

**9th Annual UNISA ISTE CONFERENCE ON MATHEMATICS,
SCIENCE AND TECHNOLOGY EDUCATION**

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Mathematics, Science and Technology Education”**



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Message from the Conference Chair

The Institute for Science and Technology Education (ISTE), was established by the University of South Africa (Unisa) to conduct research in Mathematics, Science and Technology Education (MSTE). The mission of ISTE is to provide further insight into issues pertaining to the teaching and learning of mathematics, science and technology in our education institutions and to provide post-graduate education in MSTE.

The teaching and learning of mathematics and science continue to be a bane to many communities worldwide, including South Africa. On the other hand, however, there are countries that have managed to come up with innovative initiatives to improve the quality of mathematics, science and technology education. It is against this backdrop that a need for a forum, that became to be known as ISTE Conference, was identified. The forum is largely intended to deliberate on possible ways and means to better the learner (school and tertiary) performance in mathematics, science and technology by exploring challenges and identifying deficiencies and weaknesses common in the mathematics, science and technology classrooms. Hence, the theme of the ISTE Conference is 'Towards effective teaching and meaningful learning of mathematics, science and technology'. ISTE organised its maiden Conference in 2010.

Lastly, ISTE Conference sincerely thanks the Unisa College of Graduate Studies; South African National Parks (SANPARKS), Casio and Vivlia for the helpful support and vital sponsor.

Appreciations are also extended to the membership of the Organising Committee. Lastly, the Conference will continue to value the indelible interest and persistent patronage of the delegates.

LD Mogari
Conference Chair

Review Process

The ISTE Editorial Committee received 86 manuscripts in the fields of Mathematics, Science and Technology Education. The manuscripts were given to experts in the respective fields for blind review. Each manuscript was reviewed by two experts. On receipt of the reviewers' comments the sub-Editors of each field considered the reviews and if an agreement was not reached by the two reviewers the paper was sent to a third reviewer. The reviewers' comments were then sent to the respective Authors to make the necessary improvements. The authors had to write a letter indicating how they have addressed all the corrections and submit it back to the sub-editors. The subeditors made sure all the corrections were done. From the 86 manuscripts received, 33 were rejected. Of all the manuscripts received, 53 (61.6%) were eventually published in the ISTE 2018 Conference Proceedings. Of this number, 49 (89%) manuscripts were authored by non-Unisa affiliates.

List of Reviewers

The organising committee of ISTE 2018 would like to immensely thank the following reviewers who painstakingly reviewed the conference papers. Their efforts are well appreciated and acknowledged.

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Plenary speakers

Professor Werner Blum, University of Kassel (Germany)



QUALITY TEACHING OF MATHEMATICAL MODELLING IN SECONDARY SCHOOLS – EXAMPLES, FINDINGS, CONCEPTIONS

Abstract: Mathematical modelling, that means translating between real world contexts and mathematics, is a key competency that each student ought to develop through mathematics instruction at school. The lecture presents examples of mathematical modelling tasks suitable for secondary schools, refers to empirical findings about the learning and teaching of mathematical modelling, presents a tried and tested teaching unit for mathematical modelling in grade 9 and emphasizes the importance of teachers' professional qualifications. Several aspects of the lecture such as criteria for quality teaching, empirical results on students' competency development or components of teacher professionalism should be of interest for non-specialists in mathematics as well.

Resume: Werner Blum, born 1945, got his Diploma in mathematics in 1969 and his Ph.D. in pure mathematics in 1970, both from the University of Karlsruhe. Since 1975 he has been a full professor of Mathematics Education at the University of Kassel. From 1995 to 2001 he served as the President of the GDM, the maths education society of the German speaking countries. In 2006, he received the Archimedes Award of the MNU, the German maths and science teachers' society. Since 2013, he is retired.

His research areas include empirical investigations into the teaching and learning of mathematics and into mathematics teachers' competencies. Another main focus of his work is on quality development in mathematics teaching. Among other things, he was a co-author of the German Education Standards in mathematics and is currently a member of the German commission for the final examination in mathematics. He has done a lot of work particularly in the area of modelling and applications in mathematics education, among other things as a continuing editor of the ICTMA Proceedings from 1993 to 2017 and as the editor-in-chief of ICMI Study 14 on Applications and Modelling in Mathematics Education. In 2012, he gave a plenary lecture at ICME-12 on this topic. From 2000 to 2015, he has been a member of the international PISA Mathematics Expert Group.

Professor Cedric Linder, Uppsala University, (Sweden); University of the Western Cape (South Africa)



USING SOCIAL SEMIOTICS TO OPEN UP THE POSSIBILITY OF DISCIPLINARY LEARNING

Abstract: The perspective taken for this presentation is that all communication in a particular social group is realized through the use of *semiotic resources*. These semiotic resources constitute the communicative *actions and artefacts* (van Leeuwen 2005) that get used to share meaning. In science, mathematics and technology disciplines, semiotic resources are made up of one or more *semiotic systems* such as diagrams, sketches, gesture, mathematics, and spoken and written language (e.g., see Lemke 1998). The particular meanings to be shared from these semiotic resources will have been negotiated and established within the applicable social group. From such a semiotic viewpoint, science, mathematics and technology learning can be fruitfully viewed as getting to be able to interpret and use the meaning potential of their disciplinary-specific semiotic resources. Put another way, disciplinary learning can meaningfully be viewed as a *multimodal* endeavour (Kress 2010) that calls for achieving *representational competency* (Linder et al. 2014), constituted from the coordination of disciplinary semiotic resources (Airey & Linder 2009; 2017). Effective learning in science, mathematics and technology disciplines such as chemistry and physics still presents many unsolved challenges. Efforts to deal with these challenges require extending the understanding of how such disciplinary learning takes place. Using an analysis of student-engagement data, a case will be made for seeing complex learning in terms of the multimodal *emergence* (Davis & Sumara 2006) of semiotic *transformation* and *transduction* (Bezemer and Kress 2008; Kress 2010) -- a social semiotic model of disciplinary learning.

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Linder, A., Airey, J., Mayaba, N., & Webb, P. (2014). Fostering disciplinary literacy? South African physics lecturers' educational responses to their students' lack of representational competence. *African Journal of Research in Mathematics, Science and Technology Education*, 18(3), 242-252.

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Resume: Cedric Linder's scholarship is grounded in Physics Education Research (PER). After obtaining his BSc Honours in Physics and Electronics and a teaching certification diploma from Rhodes University, he started his career teaching high school mathematics and science in the Western Cape and then went on to join the Physics Department as a lecturer at the University of the Western Cape (UWC). Cedric completed his Master's at Rutgers University in the USA on a Fulbright Scholarship and his Doctorate at the University of British Columbia in Canada on a UBC graduate fellowship. At UWC he went on to establish an internationally recognized PER group in the Physics Department, where he is currently an Emeritus Professor. In 2000 Cedric became the first Chair Professor of Physics Education Research in Sweden.

Cedric's PER division in the Department of Physics and Astronomy at Uppsala University is internationally well known for its strong promotion of, and significant contributions to, theoretical positions in PER. In the last eight years Cedric has authored or co-authored four book chapters and more than 35 articles dealing with developing theoretical framing for disciplinary learning in the sciences. This work has drawn extensively on, and derived inspiration from, connecting ideas from disciplinary discourse, semiotic systems, complexity thinking and the variation theory of learning. He serves on the editorial boards of various international journals including the *European Journal of Physics* and the *African Journal for Research in Mathematics, Science and Technology Education*, and was awarded the 2014 Medal for "Outstanding Contributions to Physics Education Research" from the International Commission on Physics Education and PER (Commission 14 of the International Union of Pure and Applied Physics). Cedric is also an A-rated NRF scientist.

Professor Ben Akpan; Nasarawa State University, Nigeria



MEANINGFUL LEARNING IN MATHEMATICS, SCIENCE AND TECHNOLOGY: TEACHING FOR 21ST CENTURY SKILLS

Abstract:The discourse begins with an examination of the concept of mathematics, science and technology (MST) against the backdrop of phenomenal, if unprecedented, growth in discoveries in science, technology and engineering. This is followed by taking a critical look at the overarching need for, and importance of, science education as well as the dual mandate of science education. The link between MST and economic growth is explored along the lines of socio-economic development. An examination of why education is vital for economic development leads to a discussion of six crucial and pivotal 21st century skills. I will argue in support of ways and means of integrating MST and 21st century skills and will end the discussion with a consideration of some approaches to teaching for 21st century skills.

Resume: Ben Akpan is a Past President of the International Council of Associations for Science Education (ICASE). He currently serves ICASE as Chair of World Conferences Standing Committee. A professor of science education, Ben's recent appointments include that with the Science Teachers Association of Nigeria (STAN) as its Executive Director. He networks for many other organizations. His areas of interest include chemistry education, environmental education, teacher education, and support for science teacher associations. Ben is a member of several professional organizations and has authored, co-authored, and edited some textbooks and several articles in learned journals. These include *Science Education: A Global Perspective* published by Springer; *Science Education: An International Course Companion* published by Sense Publishers; and *Science Education in Theory and Practice* to be published by Springer. Ben is a recipient of many commendations, prizes, and awards.

Professor Paul Prinsloo; University of South Africa



MAPPLING TEACHING AND LEARNING AS (DIS)LOCATION/(RE)LOCATION: THE ROLE OF STUDENT DATA

Abstract: Higher education has always collected, analysed and used student data for a variety of purposes such as resource allocation, strategic and operational planning, teaching and learning, as well as student support. Student data are scattered across institutions in various forms and qualities, and collected for, and used (or not) for a variety of purposes. As higher education institutions move increasingly online and digital, we have access not only to more data, but also a greater variety and granularity of student data that includes not only demographic data, but historical and increasingly real-time learning behaviour. The data may provide us with opportunities not only to better understand students' learning and contexts, but also to use the data to provide more effective, appropriate and timely support.

There are, however, a range of issues to consider in the increasing use of student data, such as seeing student data in the context of lecturer-engagement data, pedagogical structure, epistemological access, and ethical considerations. In this address I will map the potential, risks and complexities pertaining to the collection, analysis and use of student data in the teaching of Mathematics, Science and Technology education.

Resume: Paul Prinsloo is a Research Professor in Open and Distance Learning (ODL) in the College of Economic and Management Sciences, University of South Africa (Unisa). His academic background includes fields as diverse as theology, art history, business management, online learning, and religious studies. Paul is an established researcher and has published numerous articles in the fields of teaching and learning, student success in distance education contexts, learning analytics, and curriculum development. His current research focuses on the collection, analysis and use of student data in learning analytics, graduate supervision and digital identity.

Paul was born curious and in trouble. Nothing has changed since then. He blogs at <https://opendistanceteachingandlearning.wordpress.com/> and his Twitter alias is @14prinsp

MATHEMATICS EDUCATION PAPERS

Sub-Editor: Sonja van Putten



TEACHING FOR VISUAL LITERACY BY MATHEMATICS TEACHERS IN TANZANIAN SECONDARY SCHOOLS

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ABSTRACT: This study investigated how mathematics teachers in Tanzania teach for developing learners' visual literacy through multimedia instruction. The study focused on visual media used by teachers for mathematics instruction, in view of the fact that the Tanzanian Mathematics Curriculum Document (TMCD) stipulates that visual media are to be used in the mathematics classroom. The objective was to determine how teachers integrate verbal and visual representations to facilitate mathematics teaching while providing learners with opportunities to decode and encode visual information. In this qualitative case study, data was collected through the classroom observations and semi-structured interviews. The results showed that Tanzanian secondary school mathematics teachers use only still media in their classrooms, and are accustomed to integrating verbal explanation with still media, but that they were not in the habit of involving learners actively in the lesson; in fact, their teaching was uniformly teacher-centred. Despite the TMCD requirement and the willingness of the teachers to use visual media, many Tanzanian government secondary schools still lack technological and dynamic media for teaching mathematics. This study therefore concluded that teachers should be equipped and competent to use visual and dynamic media, but simultaneously, they should be encouraged to be innovative and creative in teaching mathematics, despite the lack of resources.

Keywords: Mathematics teachers; multimedia instruction; teaching; visual literacy; visual media

INTRODUCTION

Since independence in 1961, Tanzania underwent several educational reforms to improve learners' acquisition of such knowledge and skills as would be useful in conducting life as successful citizens. In 2005, Tanzania reformed the content-based curriculum to a competency-based curriculum (Ministry of Education and Vocational Training [MoEVT], 2010). The new curriculum was proposed to be used at all levels, from pre-primary school to teacher training colleges, with the emphasis is on learning, rather than content-based teaching. In teaching mathematics, prominence was to be given to teaching mathematics concepts for conceptual understanding rather than teaching for learners to memorise the content (Wangeleja, 2010).

Teaching mathematics for understanding requires active participation by the learners (Wangeleja, 2010). The purpose of visualisation is to depict and communicate information, thinking, and developing new ideas and advanced understanding (Presmeg, 2014). Espousing this notion, the Tanzanian Mathematics Curriculum Document (TMCD) produced by the MoEVT in 2010 required teachers to use a variety of visual media including still media (e.g. graphs), dynamic media (e.g. animations), and technology (e.g. calculators) in the belief that if teachers use visual media for the lesson presentation, learners will be encouraged to participate fully in the learning process. They would therefore, in theory, acquire the mathematical knowledge and skills necessary for future careers and successful lives. It is therefore important that teachers use such visual media in the mathematics class. This study investigated how teachers integrate visual media with text to facilitate the development of visual literacy in learners. What teaching styles and strategies did the teachers adopt to facilitate learner involvement and to provide opportunities for them to decode and encode visual information?

MATHEMATICS INSTRUCTION

Although mathematics is considered to be a significant subject in human advancement and life in general, this subject is often characterized as very theoretical, dominated by symbols and abstract concepts (Rubin, 1999). This makes teaching mathematics a challenge for many teachers. Complexity can be reduced by representing mathematical ideas in multiple ways (Barmby, Bolden, Raine, & Thompson, 2012; Murphy, 2011). In other words, by integrating verbal language with ‘visual language’ such as graphs, charts, tables, gestures, pictures, diagrams, dynamic computer programmes and other visual representations or illustrations, difficult concepts become more accessible. According to Naidoo (2012) and Murphy (2011), such integration may reduce the abstractness of mathematical concepts and contribute to learners’ development of understanding and information recall. However, according to Murphy (2011), visual literacy is an essential skill for interpreting visual language. Herein lies the problem: learners will benefit through active involvement in interpreting the visual media used to stimulate their interest and understanding, but only if they are visually literate (Murphy, 2011; Tillmann, 2012).

Visual literacy

Although visualization is not a new concept in learning mathematics, the use of visual thinking and acknowledgement of learners’ preferences regarding visualisation are relatively new (Presmeg, 2014). Visual information is foregrounded in the 21st Century where people gather and disseminate textual and visual information through varied technology such as the internet, cellular phones, tablets, and television. In an era where time is money, people depend on and prefer visual information to textual information. It has been scientifically verified that almost 90% of the information that enters the brain is visual and this visual information is processed much faster than contextual information (Aisami, 2015; Roux, 2009). Living in a visual era does not necessarily mean that learners possess visual literacy skills (Felten, 2010) or are able to communicate visually (Hattwig, Bussert, Medaille & Burgess, 2012). There are various definitions for visual literacy, however, in most cases the definitions are based upon the purpose and contexts of the study. Hattwig *et al.* (2012) and Tillmann (2012), view visual literacy as a group of competencies that enables an individual to understand, interpret, use, generate, and evaluate visual images or messages. These may take the form of still media (i.e. graphs, charts), dynamic media (i.e., animations), and technology media (i.e., computers, calculators). In the mathematics classroom, these competencies are at best integrated with the instruction around which the lesson is built.

Integrating visual media with instruction

Visual media are recognised as indispensable in mathematics instruction because of their role in enhancing the teaching and learning of mathematics. Visual media can be defined in terms of Presmeg’s (2014, p. 636) notion of “any external representation with a visual component”. The Tanzanian Mathematics Curriculum (MoEVT, 2010) requires the use of both still and dynamic media in teaching various mathematics topics such as congruency, similarity, geometrical transformations, logarithms, and statistics. Graphs, charts, tables, calculators, computers and other visual media are important tools in translating complex and abstract mathematical ideas into something accessible to learners, at the same time, improving recall (Okita & Jamalain, 2011). A realistic visual teaching and learning environment can also involve learners more efficiently in the learning process (Ramirez, 2012; Reddy, 2007), more so than can be done by listening or absorbing the teacher’s direct instruction (Cai, Perry & Wong, 2009; Portman & Richardson, 1997). A case in point: if, for example, a teacher tries to describe the characteristics of quadratic equations by using only verbal explanations, it may be difficult for learners to grasp the concepts. However, the integration of verbal explanations with graphic representation may greatly facilitate understanding. According to Vasquez (2010, p. 1), “a good sketch is better than a long speech”. Visual language is both concise and precise, so sophisticated ideas can be communicated more quickly and easily than would be the case with verbal language alone.

Visuals should not be used alone, however. Murphy (2011) and Suh and Moyer (2007) contend that mathematics knowledge and understanding are developed through different modalities involving verbal explanations, visual representations and numbers. However, visual literacy is not an automatic human skill and has to be developed and improved through training and practice (Felten, 2010; Hattwig *et al.* 2012). It is through regular guided and meaningful practical work that learners can acquire visual literacy skills.

Conceptual framework

The conceptual framework consists of two parts: teachers' instruction, and visual media used in the mathematics class. Visual media can be divided into still media and dynamic media. Holzinger, Kickmeier-Rust and Albert (2008) define still media as images, such as pictures, graphs, charts, tables, drawings, maps, gestures, and other diagrams or visual information. Dynamic media refers to media where there is an element of movement or even interaction and is divided into interactive media such as physical and virtual manipulatives, simulations; applications and software packages such as Geometer sketchpad; and non-interactive media such as animations and videos (Holzinger *et al.*, 2008). Technology such as calculators, computers, and other smart devices, facilitate multimedia instruction (Glenn & D'Agostino, 2008). Teaching for visual literacy requires a learner-centred approach or combination of a teacher- and learner-centred approach. Learners should be actively involved during class time through meaningful learning activities; decoding (using, interpreting and evaluating) and encoding (generating and explaining) visual information (Bamford; 2003; Cheunga & Jhaverib, 2014; Murphy, 2011; Tillmann, 2012; Vasquez, 2010). Multimedia instruction proposes that the educational message be delivered using both verbal explanations and visual images to enhance learners' understanding (Mayer, 2005; Mayer & Moreno, 2010).

METHODOLOGY

This is a qualitative case study. Purposive sampling was used to select three Form 2 (second year of secondary school) mathematics teachers from three government secondary schools in the Ilala District in Dar es Salaam. The teachers were purposively selected and the inclusion criteria were Form 2 mathematics teachers having a minimum of five years' mathematics teaching experience and holding a Bachelor's Degree of Education or any other appropriate Bachelor's Degree. Teacher A is 55 years old, holds a Bachelor of Business Administration with Education degree and has 31 years of mathematics teaching experience. Teacher B is 32 years old, holds a Bachelor of Science degree and has eight years of mathematics teaching experience. Teacher C is 34 years old, holds a Bachelor of Education degree and has six years of mathematics teaching experience.

Each teacher was observed three times and interviewed individually immediately after the last observation. The observations provided information on specific aspects associated with teacher-centred and learner-centred teaching styles used during instruction as well as the classroom activities which provided the learners with the opportunity to encode and decode visual messages. Through the interviews insight was gained into the teachers' level of understanding of visual literacy; its role in teaching mathematics in general as well as their motives for using particular media in the observed lessons. The data obtained from the observations and interviews being video- and audio-taped respectively and using observation and interview schedules, were analysed according to the themes of the conceptual framework of this study. Ethical approval to conduct the study was obtained from the Faculty of Education of the University of Pretoria's Ethics Committee and permission to conduct the study was sought from the Tanzanian MoEVT, and the District Education officer. Informed consent and assent letters were also signed by the teachers and learners respectively.

RESULTS

Teachers' teaching styles

Teacher A was observed while teaching Similarity and Statistics. The class had 40 learners. All three observed lessons were dominated by explanations and demonstrations done by her, writing notes on the board that learners had to copy and asking basic oral questions such as: "The two triangles are similar under which condition?"; "How many book shops were there?" (based on a pictogram on a chart); and "Isn't it?" to which learners replied "Yes".

Teacher B was observed while teaching Sets and Trigonometry, in particular, angles of elevation and depression. The class had 41 learners. All three observed lessons were characterised by chalk and talk teaching as he explained and demonstrated the work on the board. During the lessons, he assessed learners' understanding by asking them: "Did you get the point?"; "Are we together?"; "Is it right?" and "Is that clear?" to which learners replied in chorus, "Yes".

Teacher C was observed while teaching Statistics and Trigonometry. The class had 95 learners. All three lessons were characterised by demonstrations and involving learners through straightforward and factual questions such as "What is the formula for simple interest?"; "How do we find the class mark of the class interval?" and later "By formula, class mark is equal to upper limit plus lower limit divided by what?" At the end of his explanations, he allowed the learners to work in groups and occasionally asked learners to demonstrate their answers on the chalkboard. During group work, most of the learners did not attend to the work and were talking about non-mathematics issues.

In summary, all three teachers used a teacher-centred approach and traditional teaching with inadequate multimedia and group work as teaching strategies. Teachers gave the following reasons for their use of traditional teaching: not enough time for creativity, length of the syllabus (too full), lack of resources, class sizes, no training and knowledge of using other teaching styles and strategies, belief that learners learn best from direct instruction, disciplinary problems, and a school system that does not allow other forms of teaching, despite these being prescribed in the curriculum.

Integration of visual media and text

All three teachers used still media such as graphs, tables, diagrams, pictograms and charts in all their lessons. Only Teacher A also used physical manipulatives to demonstrate similar triangles and had models such as geo-boards that she could use. Teachers' replies regarding the use of computers were: "I would like to use them, but the computers we have are used in teaching computer literacy" (Teacher A); "We have few computers for academic office use only. ... I would like to teach mathematics using new technology such as the projector or laptop. It is time now for Tanzanian teachers to teach mathematics using new technology" (Teacher B); and "We have only one computer and it is for the school secretary only" (Teacher C). Regarding the use of calculators, Teachers A and B mentioned they do not have calculators and Teacher C said: "Learners at O-level are not allowed to use them during the national examinations, therefore it is useless to use them". All three teachers however believe that learners learn best without calculators; they prefer that the learners do the calculations themselves to better understand how to get to the answer. Teacher A explained as follows:

"We have no calculators at all. However, it is better for learners to learn themselves because when calculators are used they cannot get the concepts. Actually, they cannot follow the steps of doing calculations such as division with calculators. Rather to use the calculators is better to teach them step by step in order to know how to reach at the answer instead of using a short cut way (calculators). Personally I don't like the use of calculators".

The teachers preferred to explain a new concept in words initially, then used visual media to demonstrate the concept and further explain it, finally writing a summary of the theory on the

board. More examples were done from the textbook using oral explanations with still media followed by the teacher writing the solution on the board. All three teachers explained that they find the use of text (written and verbal) in combination with visual media useful in their explanations as visual media contribute to quicker and better learner understanding.

Learner participation

Although all three teachers gave homework to the learners in which they were required to both decode and encode visual information, but during class time there was little evidence of the learners being actively involved with the visual media. In her Statistics lesson, Teacher A required the learners to interpret the pictogram on the chart when she asked how many bookshops there were. During the trigonometry lessons, Teacher B gave the learners the problem: *Find the height of the tower if the angle of elevation of the top of the tower is 34° from a point 20m from the ground level*, requiring them to use visuals to solve the problem. He also asked them to find the value of $\tan 60^\circ$ which they had to read from their mathematics tables (they did not have calculators). During the Statistics lesson, Teacher C gave the learners a problem where they had to use the given data to draw a frequency distribution table. Apart from these activities, learners were only passively involved, watching their teachers decode and encode visual information. Apart from these examples, the teachers only involved the learners through basic and straightforward oral questioning, requesting them to pay attention and to copy the work from the board. The teachers' main reasons for not allowing learners to do activities during class time were time constraints and a jam-packed syllabus that needed to be worked through. Teacher A said: "But during the subject clubs (afternoon activities) normally I involve learners in the learning activities that require them to generate visual representations or make visual aids". Teacher B's answer was that he usually requires learners to perform tasks, but: "[t]he authority needs us to accomplish the syllabus which is too long within a specified time. Thus why, most of the time, I minimize the activities that consume time which can prevent me from finishing the syllabus".

DISCUSSION

The appropriate use of technology may enhance learners' learning, but inappropriate use may in fact hinder such learning (Bransford, 2000). How technology and actually any visual media are to be used, depends on the topic and the desired outcomes of the lesson. The advantages make the effort of overcoming the difficulties worthwhile: the teachers are thus assisted in explaining such difficult concepts as reflections, space and shape, and in addressing misconceptions, particularly those that may arise from a disconnection between the mathematics classroom and the reality of the world outside. In classrooms where visual media are successfully implemented, learners are encouraged to make thinking visible and to revise and reflect particularly in problem-solving. While the participants in this study were aware of some of these advantages and even appreciated the need for the use of visual media, there was a generally observed inertia with regard to changing teaching styles to accommodate its use effectively.

Teachers' teaching styles

All the lessons observed were teacher-centred. All the teachers used traditional teaching with a hint of multimedia instruction, with one teacher integrating it with group work. They preferred direct instruction as opposed to participatory teaching strategies, because it is "easier to conduct" (Teacher A), faster, which is important because of "pressure from the curriculum" (Teacher B), and less complicated to manage when there are "too many learners in the class" (Teacher C). This is contrary to what has been prescribed in the TMCD, in which teachers are required to use participatory teaching strategies such as cooperative learning rather than those that do not encourage learners' participation (MoEVT, 2010; Wangeleja, 2010). It follows from the literature (Murphy, 2011; Naidoo, 2012) that when mathematics instruction consists not only of text, but allows learners to use different visual media, learners' understanding of the subject matter is enhanced. The problem may be that teachers do not know what and how these strategies should be

used during instruction, as Teacher C replied during the interview: “I have no idea of other strategies”.

Integration of visual media and text

Despite the fact that the TMCD (MoEVT, 2010) prescribes the use of various visual media for mathematics instruction, these teachers mainly used still media. The reason was the lack of media resources at their schools. This is not exclusive to Tanzania, but is a reality in urban and rural schools in many countries all over the world (Moila, 2006). Physical manipulatives such as geo-boards, can be collected and created by teachers and learners, using available resources or even waste material. Although teachers may use calculators, they do not recognise their value. A need has been identified that teachers need training in the efficient use of calculators during mathematics instruction.

The teachers were nevertheless positive and willing to use dynamic media such as software packages and YouTube videos, as well as technology such as computers and projectors, but they felt that they lacked training, knowledge and skills. These teachers felt that they had insufficient time in class to make it viable to use media, the value of which was not clear to them. They were comfortable and au fait with using still media alongside of verbal explanations, but they were not able to bring in media with a view to assisting learners in developing critical thinking, communication skills and understanding of new and sometimes abstract and complex mathematical concepts. They used media to illustrate what they were saying in order to bring about understanding:

“I usually use both verbal and visual information to teach a new concept. The problem is the language because not all learners can figure out what is written. To make them understand easily, I try to draw some figures instead of using words alone. When you teach by showing them the picture or an image or an object, they get the concept within a short time rather than by using words alone.” (Teacher B)

The value of combining text with visual media during direct instruction cannot be denied. Giving the learners only one problem from the textbook at the end of the lesson involving decoding and encoding still media such as graphs, tables and drawings (Teachers B and C), is not sufficient to optimally develop learners’ visual literacy.

Learner participation

An essential element in the use of visual media for mathematics instruction is learners’ full and active participation in the learning process through various lesson activities. According to Reddy (2007), using visual media in decoding and encoding activities in the mathematics classroom makes a teaching environment more learner-centred. Teachers A, B and C frequently involved learners in the lesson discussion, but only through asking simple oral questions. The sort of learning activities that can enhance learners’ in-depth understanding were not implemented at all by these teachers.

CONCLUSION

Teaching for visual literacy is essential for the following reasons: the demands of the 21st Century require most information to be presented visually (Aisami, 2015; Roux, 2009); learners prefer to work with visual media and technology (Reddy, 2007); and optimal learning takes place when the brain processes visual and text information simultaneously (Aisami, 2015). The teachers in this study did not comply with the requirements for effectively teaching for visual literacy. The ultimate goal in teaching mathematics for visual literacy is to enhance learners’ procedural and conceptual understanding of complex and abstract mathematical ideas as they translate these ideas into more visible and accessible concepts (Murphy, 2011; Naidoo, 2012). The lack of resources and time may in fact account only partially for the absence of teaching for visual literacy in these mathematics classrooms: a lack of knowledge and skills regarding appropriate teaching styles and strategies in

involving learners in the decoding and encoding of visual media must be considered as equally important. This would explain why the teachers are not complying with the TMCD.

While it may not be possible to provide classrooms with the ideal media that would enhance visual literacy, it is possible to assist teachers to make use of the available media in a creative and innovative way. In fact, having such media does not guarantee that teaching for visual literacy would take place effectively. Instead, investing in the teachers' knowledge and skills in this regard would facilitate the effective use of the media that actually are available. Ideally, a teacher development programme involving workshops, seminars and conferences should be introduced. In such a programme, teachers' knowledge and skills could be developed in terms of:

- What teacher-centred and learner-centred teaching styles involve.
- What the different teaching strategies are and how teachers can successfully and appropriately integrate traditional teaching with other strategies, in this case with special reference to multimedia instruction.
- Effective usage and production of still and dynamic media.
- Effective use of technology such as computers and data projectors, but in particular, the use of calculators in supporting the teaching and learning of mathematics.

The question which arises from this study is, how generalisable are its findings in terms of other developing countries? Answering this question may inform teacher training programmes in a significant way. It may be an assumption that trained teachers will know which media to use and how to make appropriate use of such media. This study has shown that such an assumption is unfounded. Specific training in this regard, particularly in terms of efficient implementation of learning and teaching support material, should be included in teacher training programmes.

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MULTILINGUAL MATHEMATICS TEACHERS' USE OF VERBAL LANGUAGE TO EVOKE VISUAL REPRESENTATIONS

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ABSTRACT: This paper reports on an aspect of a study that *inter alia* looked at three purposively selected grade 11 multilingual mathematics teachers' use of verbal language to evoke visual representations during the teaching of geometry and trigonometry. Results of this study showed that teachers in the observed multilingual high school classes mostly used every-day words to evoke mental pictures of some mathematics concepts. Teachers also used isiXhosa names to describe some mathematical constructs. In situations where words or phrases were not immediately available, teachers used illustrations from the learners' environment. This paper concludes that while the use of everyday words, phrases and illustrations has many socio-cultural advantages attached to it, teachers should ensure that accurate mathematization is nevertheless prioritized and achieved through such efforts, especially at higher grades of school learning.

Keywords: Visual representations; multilingual; language; code switching

INTRODUCTION

The importance of using verbal language to improve learners' access to conceptual understanding of mathematical concepts is increasingly becoming urgent. Teachers' verbal language is crucial as it is used, among other things, to kindle relevant mental images necessary for understanding mathematics concepts. Sadoski and Paivio (2013) aptly assert that in the teaching and learning of mathematics, without the use or activation of mental representations, no meaning can be achieved. Teachers' choice of words both in the language of learning and teaching (LOLT) and the learners' home language should ideally be used to create meaning thereby making learning possible. In addition, the teachers' language should activate appropriate mental images and other representations that will produce meaning during learning. This study specifically looked at teachers' choice of words and verbal illustrations in their home language when teaching mathematics to English second language learners. Our interest was to understand how secondary school teachers use words and illustrations in the learners' first language to stimulate visual thinking in their learners. We were inspired by our own observations and experiences that when teaching, the language used to describe a particular concept may actually result in different and often unanticipated understandings of the same concept. For example, the word 'five' may suggest a quantity aspect (how many), a spatial aspect (five units above, five units below), equivalence (Davis, Goulding & Suggate, 2017), distance (five units from), combinations, and unit of measurement, among others.

In South Africa's many rural and townships schools, mathematics teaching occurs predominantly through code switching which Adler (2001) refers to as the alternate use of two or more languages in one conversation. While code-switching is crucial and has benefits, the use of learners' first language through code switching needs to help create appropriate meaning and foster conceptual understanding. This study views teachers' incorporation of learners' first language through code switching as a potential resource available for multilingual teachers and their learners to use to enhance teaching and learning (specifically visualizing). This paper seeks to answer the following questions:

1. How do mathematics teachers use learners' first language through code switching to evoke mental pictures?
2. What verbal illustrations, in learners' second language, do teachers use to enhance visualisation of mathematical concepts?

LANGUAGE AND VISUALISATION

In the teaching and learning environment, language is pivotal. Mathematics is considered as a "universal language" that transcends cultural, political, geographical, linguistic and any socially oriented differences. Teachers generally make use of words to awaken curiosity and stimulate the imagination in the minds of learners. These imaginations often translate to specific images or visualisations as the learners' attempts to make concepts visible. The mental images that learners create form the basis of how they visualize mathematical concepts and ideas. Arcavi (2003) defines visualizations as

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

For the purpose of this paper, emphasis is placed on visualisation as an act or process of putting or representing mathematical concepts into visible form internally in the mind or externally on paper or through other technological tools. We argue that in order for learners to form appropriate and meaningful internal visualisations, where they are required to recall necessary mental pictures or images when solving mathematical problems, requires teachers to use appropriate language that will meet the desired end. Teachers need to be sensitive to the idea that their use of language helps learners generate their own images that will be associated with a given concept. In speech, words often cause listeners to retrieve specific visual mental images of targeted objects. In this regard, Mesarosova and Mesaros (2011) assert that a verbally evoked image is a fictive image or representation of a mathematical concept, which is induced by the teacher in the learner's conscience mostly by means of verbal impulses. Naturally, such teacher language practices take advantage of learners' prior knowledge or experience of the concept taken from their day-to-day lives and contexts.

Visual images, used to create visual language are inherent in mathematical concepts whether they are verbally or pictorially represented. Visual language in mathematics is a process of communicating a mathematical concept through the concurrent use of images and text. It involves a very close and careful integration and symbiosis of words and images. When one is removed, the remaining communication becomes unclear. Thus, as argued by Murphy (2009) "visual images underlie the language of mathematics at every turn." (p. 5). Studies have shown that the integration of verbal and visual elements yields better results than when text is presented separately from visual elements (Mayer, 2003). The use of text or visuals only may not achieve intended results. We thus argue that when teachers use illustrations from the pupils' first language (that is, from their immediate home context) for mathematical purposes, this authenticates, legitimizes and concretizes learners' learning. The importance of using visual representations in mathematics education needs to be seen against the contribution it makes to the development of understanding and intuitional perspectives (Mesarosova & Mesaros, 2011). Using or evoking correct visuals in learners' minds allows them to see and understand mathematical relationships. Teachers' use of appropriate language that draws on pupils' familiar images enable connection making. When the teacher draws from the learners' environment, it improves connecting new concepts to previously known information.

Research has shown that language that is intertwined with visual learning and thinking approaches is beneficial to learners who are taught mathematics in a language not their first. In addition, Marentette (2018) for example, asserts that creating visual explanations improves retention of information and deeper understanding of complex concepts. In light of this, students thus benefit from learning through visual forms of communication. When the visual, verbal and the numerical co-emerge conceptual understanding is achieved. In order for teachers to capitalize on learner's experiences and prior knowledge, but where this is done mainly in the second language, there are moments when teachers should use learners' first language to help them remember and relate to these experiences and thus make connections to the taught concepts. In such instances, choice of words and phrases that evoke interesting and relevant images that will resonate with a given concept is thus crucial. Murphy (2009) observes that when teachers express mathematical ideas so that their words, associated images and numbers are working together seamlessly then true communication results.

In a situation where learners are taught in their second language it is particularly important that teachers provide visual cues, graphic representations, gestures, regalia, and pictures during their teaching. It is argued that such practices offer learners the required opportunities to manipulate objects and images to master mathematical concepts and vocabulary.

THEORETICAL FRAMEWORK

This study was informed by the situated-sociocultural theory as envisaged by Moschkovich (2002), specifically with regard to the role of language in multilingual classroom communication and cognitive development. Situated in this study refers to "local, grounded in actual practices and experiences" (Gee, 1999, p. 40). Central to Moschkovich's situated-sociocultural theory is the recognition of the pivotal role played by two or more languages in each situation as a resource to communicate mathematically. The theory describes languages used in communities as a resource for teaching and multilingualism as a competency in mathematical communication. The situated-sociocultural theory views teaching mathematics as a social activity that employs multiple materials, linguistic and social resources to enhance instruction (Moschkovich, 2002). The theory assumes that mathematics teacher's language practices should be grounded in practice while at the same time connected to mathematical concepts.

SAMPLE AND RESEARCH PROCESS

A case study approach was used to enable us to gain a detailed view of three selected teachers' verbal and visual language practices manifested during teaching mathematics in multilingual grade 11 classrooms. Three grades 11 mathematics teachers from three districts in the Eastern Cape Province of South Africa participated in this study. Each teacher and his/her class constituted a case. The three teachers identified as Teacher A, Teacher B and Teacher C were purposively selected. Data were obtained through observing five consecutive geometry or trigonometry lessons per teacher. Lesson observations were used to identify language practices of these teachers. At the end of each lesson, each teacher was interviewed. The interviews focused on language practices that the participating teachers demonstrated during the lesson.

With the consent of the Department of Basic Education, school principals and the teachers, five lessons were video recorded of each teacher. An isiXhosa first language speaker transcribed the videos for us. Each video was then analyzed qualitatively. During the lesson observations, we focused on isiXhosa words and phrases that the teachers used. We then identified those that were used to evoke visual images during teaching. We were also interested in scenarios, descriptions and illustrations that teachers took from learners' local environment and how they used them during their teaching. Trends and patterns of words, phrases, descriptions and illustrations that emerged during the lesson observations were then followed up during the interviews.

VALIDITY

Validity was ensured by using multiple sources of evidence such as lesson observations and interviews. In order to ensure the integrity of the language used in the lessons transcriptions were done by an experienced transcriber and were verified by two isiXhosa first language speakers.

RESULTS

Teachers' use of everyday words to visually evoke mental pictures of a concept

This section focuses on some of the words teachers used to help pupils remember concepts or retrieve concepts from their minds that were relevant for solving given tasks. For the purposes of this paper, only *fumana* will be considered.

Fumana - Find

All three teachers used *fumana* extensively in this study to ask questions. *Fumana* is used in everyday life when someone is asked to find something, whether it is hidden or can be readily found. In mathematics, *fumana* (find) means using mathematical methods to obtain, locate, detect or gather the values, quantities or any mathematical construct in question. Thus in situations that needed students to calculate or just to observe and state required answers, *fumana* was used. Below are extracts from their lessons:

Teacher A: Ku-ABD, sizamfumana njani u-BD? (For ABD, how can we find BD?)

Teacher A: Now calculate BC. Sizamfumana njani u-BC? (How are we going to calculate BC?)

Teacher B: Cofa ecalulatini yakho, kwi-reference sifumana bani (use your calculator, what do we get as a reference).

Teacher B: Sizawuyifumana njani i-value ka-A there? (How do we find the value of A there?)

Teacher C: Xa u multiplier u "b" no "a", surely uza fumana u "ba" (when you multiply "b" and "a", surely you will get "ba").

The everyday use of *fumana* retains the same meaning as when used for mathematical purposes. All teachers used *fumana* frequently to mean 'calculate', 'find' or 'what we get.' Hence *fumana* has multiple meanings both in everyday use and when used for mathematical purposes. The ability to use everyday words in a mathematical way has advantages of visually bringing an everyday mental picture into the scientific field of teaching. Because *fumana* carries the same meaning in both the everyday life and the mathematical realm, it helped the teacher to make connections. During the interview, Teacher C said, "*everyday terms that have the same meaning when used to teach maths helps link my learners' life outside school with mathematics.*" Home language terms with multiple meanings are also important because they can be used in various contexts during teaching. Moschkovich (2002) asserts "because there are multiple meanings for the same term, students who are learning mathematics can be described as learning to use these multiple meanings appropriately." (p. 194). Viewed from such a perspective, the use of such isiXhosa terms presented more advantages than limitations. *Fumana* is also used throughout school from the foundation phase onwards - hence the reason why it was used comfortably with such abundance by all teachers in this study. Considering the social context in which *fumana* was used, learners were appropriately prompted to seek solutions of given tasks.

During the interviews, Teacher B explained what 'undefined' was by translating it into isiXhosa. The term 'undefined' was code switched as *ayifumaneki* by Teacher B meaning, 'that which we cannot find or get.' The root word here is still *fumana*.

Researcher: The gradient was undefined, what is the isiXhosa term for 'undefined?'

Teacher B: Undefined *ayifumaneki* (you cannot get it) you can't get to the solution. *Ayifumaneki* even though they say something is undefined, the thing is there but you cannot define it. *Ja* it doesn't exist, *ayikho ayifumaneki* (it's not there you cannot get it) (Interview 2).

The use of *ayifumaneki* helped to enlighten the concept of an undefined situation. Additionally, *Ayifumaneki* was intended to help learners visualize that some situations, like, the gradient of perpendicular line, is undefined. This can also be applied to other cases in mathematics that are undefined or where a solution cannot be calculated or found. The use of familiar words in the learners' home language for mathematical purposes may assist learners to visualize situations that may not be so easy to understand.

IsiXhosa Names of Mathematical Constructs

In this study, teachers used a combination of borrowed words and indigenous names for various mathematics constructs. For the purposes of this paper, we will only consider quadrilaterals.

Ikwadrilatherali - Quadrilaterals

During the teaching of circle geometry, all teachers briefly looked at quadrilaterals and their properties. This was to prepare learners to tackle cyclic quadrilateral concepts later on.

Teacher A: *Ikwadrilatherali i-shape enjani kanene?* (What kind of a shape is a quadrilateral?)

Teacher B: Talking of a quadrilateral, we mean *ipholigoni enamacala amane, siyavana sonke? Imizekelo includes ikayiti, isikwere, uxande, ipharallogram* (We mean a polygon with four sides, are we together? Examples include kite, square, rectangle, and parallelogram).

Teacher C: *Jonga for ucalane okwisangqa, all corners should touch i-circumference* (look for the cyclic quadrilateral, all corners should touch the circumference).

The use of *ikwadrilatherali* by Teacher A is considered in this study as providing little advantage in visually assisting learners to understand the polygon. This is because the borrowed form is not as explicit and visually vivid as the isiXhosa translation Teacher B used, that is, *amacala amane* (four-sided). The choice of descriptive translations such as these provides a visual image of the type of polygon that is being discussed. This was also noted in Teacher C's reference to the cyclic quadrilateral as *ucalane okwisangqa* (four-sided inside a circle). The isiXhosa translation used for cyclic quadrilateral combines two familiar words forming another concept that is visually transparent in nature (see Chikiwa & Schäfer, 2016). This study argues that the use of such terms helps learners to visualize the concepts because of the immediacy and familiarity of the terms used to isiXhosa first language speakers.

Lack of IsiXhosa Terms and Use of Situated Illustrations

In the teaching of geometry and trigonometry, the participating teachers concurred that some mathematical terms were not easy to translate into their home language. In those cases where the mathematical concept lacked an equivalent word or phrase in isiXhosa, either the teachers were using descriptions of those words or they sought illustrations from their pupils' environment. Such language practices were perceived as ways of helping learners visualize mathematical concepts.

In the interview, Teacher A explained the acute and obtuse angles using isiXhosa analogies. She concurred that actual names for these terms in isiXhosa were not easy to find hence the use of visual explanations or descriptions to identify these angles.

Researcher: How do you explain acute, obtuse and reflex angles in isiXhosa?

Teacher A: Mh-h we don't have those words in Xhosa. I use descriptions for example acute angles, *i-angles ezingaphantsi ko-90^o* (angles below 90^o). Less meaning that *zingaphantsi* (they are below). *I-obtuse*, it means *zingaphezulu ko-90^o* but *ngaphantsi ko-180^o* (Obtuse means more than 90^o but less than 180^o) (Interview 1).

During the interviews, Teacher A could describe promptly acute and obtuse angles in isiXhosa. The illustrations were done in commonly used language familiar to learners. The isiXhosa terms are thus

more elaborate and easier to understand for learners than being taught in a second language that is less familiar. The demonstration below presents a visual picture of the positioning of these angles if they are presented on a number line. A trend that emerged with all participating teachers was their use of code switching for illustrating a point by using everyday scenarios. In the interviews, we followed up on this tendency with Teacher B when he was dealing with parallel lines. He gave two everyday examples to illustrate parallel lines, that of railway lines and lines on a freeway.

R: How do you explain the concept of parallel lines in class using their home language?

Teacher B: I normally relate parallel lines with *iziporo* (railway lines). If you look at *iziporo pha ku-train* (railway lines for the train), they will never meet even if they are taking a turn they all taking a turn. So basically it's another visual and familiar example of parallel lines. Even *umgwaqo lapha ku-freeway* (the freeway roads), your lines that are there on the freeway are also parallel (Interview 2).

The teachers in the interviews reiterated the need to tap into locally available everyday visual illustrations that are able to present visual aspects of mathematical concepts. Teacher C also gave a similar illustration during the interviews.

Teacher C: Look at the train, *pha i-train mos ineziporo zibini* (has two rail lines), if those two would try to meet, it would get dangerous and people would die. So those two tracks are parallel. This will give them confidence as you use known visible things around them (Interview 2).

Learners in these classes were familiar with railway lines and highways. The teachers thus suggested that these would be appropriate phrases to use to stimulate the visualisation of the parallel lines concept. Both teachers agreed that any scenario where two lines will not meet would be suitable to illustrate parallel lines. Teacher C added that taking visual examples from their immediate environment would boost learners' confidence. The use of such illustrations from everyday life assist learners to internally visualize embedded mathematics concepts.

The lack of precise mathematical terms (that is, the lack of a mathematics register in isiXhosa) encouraged and forced the teachers to use illustrations that would evoke the visual impressions of concepts in the learners. These illustrations were taken from students' everyday environments. The teachers used mostly isiXhosa when giving these illustrations. For this study, it was important to understand how mathematics teachers' everyday illustrations were used to provide linguistic resources for mathematical communication.

SUMMARY AND CONCLUSION

In summary on answering our research question 1; participating teachers in this study used everyday vocabulary and descriptions of mathematics concepts in their learners' first language to help improve learners' conceptual understanding. While teachers in this study did not extensively use this practice of using learners' first language words and descriptions to help evoke mental pictures, they used everyday words, which were familiar to their learners, for mathematical purposes. Teachers in this study did not plan how and when to use the learners' first language, it occurred spontaneously. We argued though that the use of language to visually represent and present mathematical ideas during teaching should be well planned and prepared. Teachers of mathematics, who understand how words can be used to visually stimulate conceptual teaching, should be conscious to choose words that utilize imagery to enhance learning.

In order to answer research question 2; the teachers' use of illustrations taken from everyday life during teaching, to elaborate geometry and trigonometry concepts, is commendable and should be encouraged. However, these should be well planned for such practices to yield the best results. Ad hoc illustrations may be more harmful if not properly planned and well thought out. A well-reasoned, sentient and astutely designed visual illustrations mixed with verbal descriptions can yield

a much more powerful and memorable learning experience than only verbal or textual description. While the use of everyday words, phrases and illustrations has many socio-cultural advantages attached to it, teachers should ensure that mathematization is prioritized and achieved through such efforts, especially at higher grades of school learning. Teachers should be taught to use language strategically so that learners of mathematics will not see it as a 'foreign language' that has nothing to do with day-to-day lives of those learning it. This is possible when teachers find appropriate and suitable words and illustrations taken from everyday life that clearly and vividly presents the concerned mathematical concepts.

In the grade 11 classes used in this study, the selected mathematics teachers tended to avoid bringing actual concrete visual aids during teaching and favored verbal and abstract approaches. Thus, the ability to use verbal language that evokes visual images appropriate to a given task is necessary. There is, thus, a need for providing adequate and appropriate academic language support to teachers of all learners learning mathematics in a language that is not their first. Teachers would need to be trained to harness linguistic resources that evoke mathematically related images from their environment for the improvement of mathematical teaching.

There is a need for much more language and content specific support for both preservice and in-service mathematics teachers of multilingual classes. Such support mechanisms should include topic-specific language demands since each mathematics domain has its own sub-register. There is also a need to explore ways to support teachers of second language learners, how to better engage and address the needs of multilingual learners in the mathematics classroom.

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SUPPORTING STUDENTS' COMPETENCY DEVELOPMENT IN THE MATHEMATICAL MODELLING PROCESS

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ABSTRACT: In the paper, we report on third-year mathematics students' mathematical modelling competency development through providing strategic support in the learning of mathematical modelling. Students often experience modelling as difficult and obstructions in the modelling process can lead towards a dead-end. Literature reports confirm the modelling task is central in the modelling experience and a carefully planned task can be used as a scaffold in learning mathematical modelling. Hence, this inquiry was conducted to provide a scaffold as strategic support for student' competency development in the early stages of a modelling cycle. Guided by the framework of the Zone of Proximal Development, key elements suggested by the metaphor *scaffolding* are considered in the learning experience. Based on an analysis of activity sheets collected through group work, an example of a realistic and an unrealistic solution are presented. Finally, suggestions for strategic support in the mathematical modelling process are discussed.

Keywords: Mathematics applications; mathematical modelling cycle; modelling competencies; scaffolding; student support.

INTRODUCTION

The mathematical modelling process is cyclic in nature and includes four elementary stages, namely, *representing a real-world problem mathematically, using appropriate mathematics to solve the problem, sense-making of the solution in terms of relevance and appropriateness, and a final reflection to examine assumptions and possible limitations* (Balakrishnan, Yen & Goh, 2010). Despite numerous challenges in the changeover between the different stages of the cycle, Stillman, Galbraith, Brown and Edwards (2007) highlight remarkable mathematical accomplishments by students moving through the modelling cycle. Some of these accomplishments include much needed modelling competencies, described by Niss, Blum and Galbraith as "the ability to identify relevant questions, variables, relations or assumptions in a given real world situation, to translate this into mathematics, and to interpret and validate the solution of the resulting mathematical problem in relation to the given situation" (2007, p. 12). In order to avoid a 'dead-end' in the mathematical modelling process or a possible lack in mathematical understanding, experts in the field propose that challenges should be addressed through a strategic intervention (Schukajlow, Kolter & Blum, 2015). This inquiry forms part of a broader research project focusing on a strategy to integrate mathematical modelling in the formal education of mathematics student teachers (Grade 10 – 12). Early findings (Durandt & Jacobs, 2018) from the broader project revealed a well-planned set of activities is required for the professional development of mathematics student teachers.

As a result, the authors implemented a strategic intervention in the form of an activity that involved two mathematics application tasks. The aim of these tasks was to support students in the development of competencies required for the mathematical modelling process, guided by the notions of the Zone of Proximal Development (ZPD) (Vygotsky, 1978), before they are exposed to more challenging tasks. The modelling task is central in the mathematical modelling learning experience and the *Guidelines for Assessment and Instruction in Mathematical Modelling Education* (GAIMME) report (COMAP-SIAM, 2016) explains the transformation from a mathematics word

problem to a modelling task as follows. A traditional mathematics word problem (requiring traditional problem solving) is transformed to a mathematics application problem (requiring mathematical applications) *by adding context*, and finally to a mathematical modelling problem (requiring the complete modelling process) *by adding interpretation*. The two tasks that were used in the intervention can be seen in Figures 1 and 2. Both these tasks can be classified as mathematical applications (according to GAIMME’s explanation) and solving these tasks would merely require ‘stripping’ the words from the problem, and the modelling process would be limited to mathematisation, mathematical procedures, and a direct contextual interpretation. A more open-ended modelling task would require substantial modelling demand from students, but the focus in this inquiry was to support novice modellers (due to their limited exposure to such tasks before) in the modelling process and in the development of required competencies. The authors attempted to provide a scaffold, following at least five of the six elements identified by Wood, Bruner and Ross (1976): (i) to enlist students’ interest in these mathematical application tasks, (ii) to simplify the tasks by regulating feedback according to particular sub-questions asked, (iii) to keep the students focused on the task by means of well-planned facilitation, (iv) to emphasise correspondences and discrepancies by discussing results in groups, and (v) to discuss a possible solution for a mathematical application problem in groups.

Mathematical Application Task 1

The daily production of a sweet factory consists of at most 100 kg chocolate covered nuts and at most 125 kg chocolate covered raisins, which are then sold in two different mixtures. **Mixture A** consists of equal amounts of nuts and raisins, and is sold at a profit of R5 per kilogram. **Mixture B** consists of one third nuts and two thirds raisins and is sold at a profit of R4 a kilogram. Let there be x kg of mixture A and y kg of mixture B.

1. Express the mathematical constraints which have to be adhered to.
2. Write down the objective function which can be used to determine maximum profit.
3. Represent the constraints graphically and clearly show the feasible region.
4. Use the graph and determine maximum profit obtained.

Figure 1: Mathematical Application Task 1

Mathematical Application Task 2

A nutritionist is performing an experiment on student volunteers. He wishes to feed one of his subjects a daily diet that consists of a combination of three commercial diet foods: MiniCal, LiquiFast, and SlimQuick. For the experiment, it is important that the subject consume every day exactly 500 mg of potassium, 75 g of protein, and 1150 units of vitamin D. The amounts of these nutrients in one ounce of each food are given in the table. How many ounces of each food should the subject eat every day to satisfy the nutrient requirements exactly?

	MiniCal	LiquiFast	SlimQuick
Potassium (mg)	50	75	10
Protein (g)	5	10	3
Vitamin D (units)	90	100	50

Figure 2: Mathematical Application Task 2

The purpose of this inquiry is to report on third year mathematics students’ mathematical modelling competency development through providing strategic support in the learning of mathematical modelling as they taken part in an activity containing two mathematical application tasks. The two research questions are: (1) can novice modellers move successfully through the elementary stages of the modelling cycle by exposing them to mathematical application tasks, and (2) have they learnt mathematical modelling competencies through this learning experience? This inquiry, that forms part of a broader research project, was conducted to provide a scaffold as strategic support for

student' competency development in the early phases of a modelling cycle while they are exposed to mathematical application tasks and before they are exposed to mathematical modelling tasks.

THEORETICAL PERSPECTIVES

One characteristic of the mathematical modelling activities in this intervention was the team problem-solving approach via collaboration. This collaboration was enhanced by the two underlying notions of the Zone of Proximal Development (ZPD) (Vygotsky, 1978), and scaffolding. The most widely known definition of ZPD is "the distance between the actual developmental level, as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 33). Following on the Western interpretation of Vygotsky's work, the notion of *scaffolding* developed almost 40 years ago (Wood et al., 1976). Other researchers in mathematics education (Anghileri, 2006; Schukajlow, et al., 2015) have also acknowledged this metaphor, which refers to the intended systematic support for an individual student by a knowledgeable adult. In this inquiry, a collaborative ZPD was made possible by student interaction in small groups as they participated in mathematical modelling activities. This focus provided a support structure or 'scaffold' for student's competency development and they could learn from the knowledgeable other.

In this inquiry, the notion of the *Zone of Proximal Development* (ZPD) can be seen as the underlying theoretical lens to explain students' cognitive development in mathematical modelling. Student cognitive development was potentially promoted by following the steps in the mathematical modelling cycle and by collaborating in groups when involved in a learning activity containing two mathematical application tasks – both serving as a scaffold to support mathematics students' increasing independence as their understanding of mathematical modelling became more secure. Wood et al. (1976), also cited by Anghileri (2006, p. 34), identified six key elements using the metaphor of scaffolding, namely:

- i. *recruitment* – to enlist the student' interest in a mathematical modelling activity, to willingly adhere to the requirements of the activity;
- ii. *reduction in degrees of freedom* – to simplify mathematical modelling tasks by regulating feedback according to the particular phases of modelling cycles;
- iii. *direction maintenance* – to keep the students focused on the task by means of well-planned facilitation by the facilitator;
- iv. *marking critical features* – to emphasise correspondences and discrepancies by discussing results;
- v. *frustration control* – to respond to student' reactions when participating in mathematical modelling tasks; and
- vi. *demonstration* – to discuss a possible solution for a real-life contextual problem.

All of these key elements were considered in planning and implementing the structured intervention in this inquiry, but in particular the first four and last element.

RESEARCH DESIGN AND METHOD

Participants, third-year mathematics student teachers at a Johannesburg University, characterised by a variety of demographical profile elements, are illustrated in Table 1:

Table 1 Demographical profile elements of participants

Profile variable (N=55)		N	%
Gender (N=43)	Female	17	39.5
	Male	26	60.5
Ethnic Group (N=42)	Asian, Indian, Coloured	2	4.8
	Black	32	76.2
	Coloured	3	7.1
	White	3	7.1
	No response	2	4.8
Home Language (N=43)	Afrikaans	4	9.3
	English	5	11.6
	Indigenous	33	76.7
	No response	1	2.3

The research design was conducted from a qualitative viewpoint (Creswell, 2013) and participants were arranged into 10 groups according to ability using stratified sampling procedures. They were exposed to the mathematical modelling activity, which contained two contextual problem-solving examples that required little ambiguity from groups about their strategies and methods. The information in both selected examples had already been carefully defined, containing all the necessary data to formulate a model, and called for a specific procedure to be employed. The activity, involving both tasks, was conducted during a 110-minute official timeslot. During the activity, the researchers were present to observe group discussions. Apart from the theoretical basis that informed this inquiry, the rationale for exposing student teachers to mathematics application tasks was informed by Chan's viewpoint (2013) that a possible starting point for the integration of mathematical modelling into the classroom could be identified via simple tasks. The researchers intended to design an activity not only to support students' in the development of mathematical competencies in the modelling process, but also to enhance collaboration between group members, and to stimulate favourable participant attitudes (also compare Durandt & Jacobs, 2018).

Task 1, on the daily production of a sweet factory (see Figure 1) required students in groups to express mathematical constraints to represent the given data, then graphically represent the constraints and lastly, to make use of the graph to determine maximum profit (Bester, Ham, Loots & Stark, 1998, p. 113). Task 2 (see Figure 2), adapted from Stewart, Redlin and Watson (2012), provided information on the potassium, protein and vitamin D content in one ounce of commercial diet food. Information were presented in the form of a table in order to compare the three different brands of diet food. Groups were expected to calculate how many ounces of each type of food should be taken per day to satisfy daily nutrient requirements. Groups submitted their strategies and mathematical solutions on a pre-designed activity sheet, designed according to the elementary stages of a modelling cycle to provide students with a scaffold.

ANALYSIS AND FINDINGS

Qualitative data were analysed by following the direct content analysis method (Hsieh & Shannon, 2005). This method of analysis makes use of existing research to guide the variables of interest (proposed categories). The three proposed categories originated from the theory on students' modelling and mathematical competencies (Stillman, et al., 2007) and the principles (accurate, realistic, precise, practical and robust) to evaluate a mathematical model (Meyer, 2012). These three coding categories, *modelling competence*, *mathematical competence* and *model capability*, guided

the analysis of the activity sheets from the different groups that were collected during the intervention (see Table 2 on the next page).

Table 2 shows an analysis of participant groups activity sheets of how the different groups displayed modelling competence, mathematical competence and model capability by solving the two mathematical application tasks (compare Figure 1 & 2).

DISCUSSION

The mathematics application activity in this inquiry involved two different tasks and did not require from the participant groups to progress through the complete modelling cycle, or to consider the implications of their decisions, or to discuss the validity and applicability of their selected mathematical models. The focus of the two tasks was on the development of modelling competencies and the researchers attempted to utilise the modelling cycle as a metacognitive tool to expose students to the early stages of the modelling cycle.

In Figure 3, the mathematical and modelling competence of group 1 is illustrated, indicating the manner in which the group structured the relevant information in a table, then expressed the mathematical constraints as two inequalities, having written down an objective function to determine maximum profit, and finally presenting the problem graphically. In addition, the objective function (as the dotted line) and final solution (at point A) are depicted in the figure.

Table 2 Analysis of group activity sheets

Initial Coding Categories	Groups										Total	
	1	2	3	4	5	6	7	8	9	10		
Modelling Competence												
Moving successfully through the first two stages of the modelling cycle.	X	X	X	X	X	X	X	X	X	X	X	10
Identifying from the available information what is relevant and what is irrelevant.	X	X	X	X	X	X	X	X	X	X	X	10
Making simplified and relevant assumptions about the situation to enable mathematics to be applied.	X	X	X	X	X	X	X	X	X	X	X	10
Mathematical Competence												
Recognising relevant variables.	X	X	X	X	X	X	X	X	X	X	X	10
Accurately representing the real-world problem mathematically.	X	X	X	X	X	X	X	-	-	X		8
Inaccurately representing the real-world problem mathematically.	-	-	-	-	-	-	-	X	X	-		2
Selecting appropriate mathematical formula - consistent with the representation.	X	X	X	X	X	X	X	-	-	X		8
Selecting appropriate mathematical formula - inconsistent with the representation.	-	-	-	-	-	-	-	X	X	-		2
Applying mathematical content knowledge correctly.	X	X	-	X	X	X	-	-	X	X		7
Applying mathematical content knowledge incorrectly.	-	-	X	-	-	-	X	X	-	-		3
Investigating more than two mathematical procedures to solve the problem.	X	X	-	-	X	X	X	X	X	-		7
Model Capability												
Accurate (model output expected to be near to correct)	X	X	-	X	X	X	-	-	X	X		7
Realistic (model based on original correct assumptions)	X	X	X	X	X	X	X	X	X	X		10
Precise (model output values should be definite mathematical quantities or falling in an closed interval)	X	X	-	X	X	X	X	X	X	X		9
Practical (sensible solutions provided)	X	X	-	X	X	X	-	-	X	X		7
Robust (relatively safe to errors)	X	X	X	X	X	X	X	X	X	X		10

All 10 groups indicated *modelling competence* in their documents as they proceeded successfully through the first two fundamental phases of the modelling cycle (Balakrishnan et al., 2010). All groups identified relevant information and made simplified assumptions about the real-world contexts in both given examples included in the task. From the category *mathematical competence*, findings indicated on the one hand, the mathematical representation used, and on the other hand, the content selection and mathematical operations performed by the different groups. All 10 groups introduced relevant variables and represented the application problems mathematically (given in two examples) although only eight of these representations were accurate. The two inaccurate representations from groups 8 & 9 contained minor mathematical errors. The entire class selected appropriate mathematical formula to solve the problems, and seven groups investigated more than two mathematical procedures, such as solving equations simultaneously, determining solutions graphically and performing matrix operations. Seven of the groups applied the selected mathematical content knowledge correctly, but the documents from three of the groups indicated mathematical errors in procedures.

Due to the carefully defined mathematical application tasks included in this inquiry, little ambiguity about the model and procedures was expected from the groups. As anticipated, all groups formulated realistic models, based on correct assumptions and prior exposure to relevant mathematical content knowledge. Groups displayed *model capability* by means of its accuracy, precision and practicality (Meyer, 2012). These criteria depended on the mathematical competencies of groups, and hence, seven of the groups formulated output values expected to be correct (referring to accuracy). The same seven groups provided sensible solutions (directed towards practicality), while the models from nine of the groups generated definite output values (indicating precision). In the case of group 8, definite output values were calculated, given by $x = 326,42$; $y = -207,14$; $z = 171,43$, but the values were impractical and inaccurate. Noticeably, a negative number of ounces of LiquiFast (y) is an unrealistic solution.

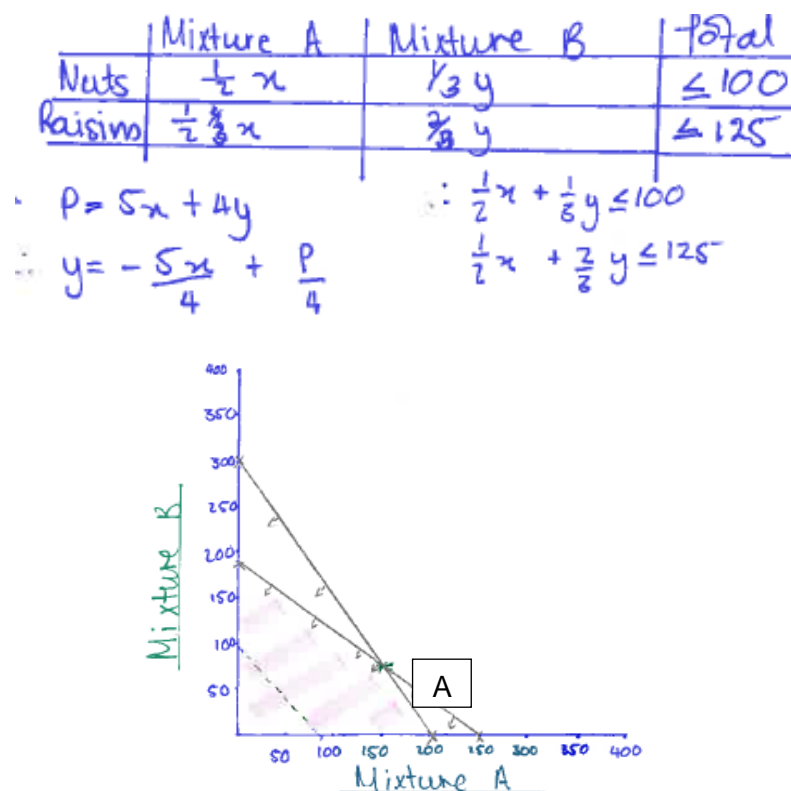


Figure 3: Example from group 1 illustrating mathematical and modelling competencies

CONCLUSION

This inquiry reports on third-year mathematics students' mathematical modelling competency development through guided strategic support in the learning of mathematical modelling. It was found that novice modellers could move successfully through the elementary stages of the modelling cycle by exposing them to an easier mathematical modelling activity including two mathematical application tasks. Furthermore, most participant groups displayed mathematical and modelling competencies and they showed an understanding of mathematical models. Some groups displayed realistic answers, while others had unrealistic answers. Finally, we conclude that participants revealed themselves as mathematical modellers although the modelling process was limited to mathematisation, mathematical procedures, and a direct contextual interpretation. This inquiry provides a basis for further strategic support and continued exposure to more open-ended modelling tasks.

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'TALK' ON GRADE 7 LEARNERS' PERFORMANCE IN MULTIPLICATIVE WORD PROBLEM-SOLVING

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ABSTRACT: This paper reports on the use of dialogue as a tool to enhance 'talk' in relation to multiplicative word problem-solving and how it influenced Grade 7 learners' academic performance. The absence of 'talk' creates a gap in the level of syntactic knowledge central to mathematical modes of inquiry practices in mathematics. 42 learners from Montshioa Township in the North West Province of South Africa participated in a classroom intervention where Argumentative Writing Frames (AWFs) to support dialogue were used in a context of multiplicative word problems. A social constructivism theory and Freire's rethinking theory underpinned the study. Constructivism theory views learning as an effective social interacting process between learners, their utterances with teachers as mediators and their environment as they become competent problem solvers. The Rethinking theory views the boundary crossing (diacognition) as dialogue where the teacher crosses over to take the position of the learner and the learner crosses over to the teacher's position. Data for this research were provided by video shots. Thematic analysis using Vygotsky's Zone of Proximal Development (ZPD), mediation and social interaction analytic tools was used. The results demonstrate that there was improvement in the learners' *talk* (discussions and argumentation after the intervention).

Keywords: Dialogue; discussions; argumentation; learner; word problem-solving; intervention; argumentative writing frames

INTRODUCTION

In most of the schools worldwide learners' academic performance in primary school Mathematics is a growing concern. The concerns cover issues of language (linguistic nature) (Planas, 2014; Sarmini, 2009; Sepeng, 2013), struggling to consider real-world knowledge and context in the solutions (Sepeng, 2013, 2014; Xin & Zhang, 2009; DBE, 2013), language of teaching and learning, and the absence of "talk" in the classroom to make and support claims (Lewis & Wray, 2002; Venkat, 2013, 2016; Webb, Williams, & Meiring, 2008).

The authors explored the use of dialogue to enhance 'talk' which seemed to make possible the teaching and learning interaction, creating new knowledge that was constructed by learners to rethink ideas, to argue, evaluate, share, examine, as well as learners understanding the conceptual underpinnings of Mathematics as they became better problem solvers (Hart, 1999; Brenner, 1998).

LITERATURE REVIEW

Word problem-solving

Mathematical word problem-solving, within the South African classroom contexts, forms part of the South African Mathematics curriculum and is used to teach learners how to model problems in primary Mathematics classrooms (Sepeng & Sigola, 2014). Jitendra, Petersen-Brown, Lein, Zaslofsky, Kunkel, Jung and Egan (2015) explain mathematical word problem-solving as a process involving the integration of a number of cognitive processes such as attention, memory and language. Sepeng and Sigola (2014) concur that solving word problems is part of a unit of the text comprising a question

and a speech that is accompanied by an authentic background story and the syntactical and rhetorical structure that needs to be explicitly clear to enhance understanding. The constructivist and socio-cultural theory was used.

Learners' mathematical academic performance in solving word problems

The section below discusses issues related to the learners' academic performance e.g. socio-cultural and historical related factors as well as linguistic related ones.

Factors associated with socio-cultural aspects and historical contexts: The socio-cultural and historical contexts pose difficulties to learners' academic performances, as learners in rural townships and in some urban schools have been marginalised (Sepeng, 2014). English Language was used as a second language in the majority of the schools. Sepeng and Madzorera (2014:218) report that culture, attitude, choice, and previous mathematical experiences also affect the academic performance of learners.

Learners' performance and factors associated with linguistic abilities : According to Reikeras (2009), low reading ability in word problems and arithmetic influence the growth in learners' academic performances. Sarmini (2009) reports that Grade 7 Arab-American learners were labelled as Limited English Proficient (LEP) because they were unable to understand the language of instruction, which was English, hence they were labelled a "minority" or "inferior" group. In almost every classroom in China, there are students with difficulties in learning Mathematics, with the prevalence varying from 4% to 10% (Xin & Zhang, 2009).

Dialogue

Rule (2015, p. 2) defines dialogue (*dialogos* in Greek) as a "conversation" or "discourse." Dialogue comprises a rationale with a specific *talk* by learners which is enhanced by the educator in making use of different types of scaffolds (Norenes & Ludvigsen, 2016), an answer, argumentation, communication, conversation, dialogue, discourse, discussion, feedback, ground rules, interaction, language, oracy, question, reciprocal recitation, speaking and listening, talk, turn-taking (Howe & Abedin, 2013), an exchange of meanings and understandings between two people or parties (Miller, 2011). Dialogue occurs in a face-to-face or at a distance code, which could either be written, spoken, visual, or sign language as well as a combination of the above applications. The researcher used discussion and argumentation in the interrogation and understanding of dialogue.

Discussion and argumentation as strategies in word problem-solving

Discussion as a teaching and learning scaffolding strategy improved learners' ability to make sense of real wor(l)d problems (Sepeng & Webb, 2012); discussion is enabled by language (Sams, 2006); and yielded a positive impact on learners' abilities to solve word problems (Jaafar, 2015). Argumentation is explained as a process where learners make a claim, provide suitable evidence to justify it, and defend the claim in a logical way (Ross, Fisher & Frey, 2009; Sepeng, 2014; Webb et al., 2008).

THEORETICAL PERSPECTIVES

The interpretivism research paradigm, central to Vygotsky's socio-cultural theory, explores participants' social world, what they think, their utterances and interactions with their immediate environment and a knowledgeable peer or teacher that facilitates the construction of new knowledge (Brenner, 1998; Creswell, 2014; Doolittle, 1997; Harland, 2017; Hart, 1999; Okeke & Van Wyk, 2015; Vygotsky, 1978; Wertsch & Tulviste, 1992). Freire's Rethinking theory or dialectical approach views true learning as dialogue viewed through boundary crossing in communication through language that is internalised by learners to bear actions that make thought and speech. Rule (2015) claims that there can be no communication without dialogue and no true learning without

communication. Freire's analysis of dialogue is viewed as a method of enquiry and a pedagogical orientation as well as a human feature (Rule, 2015, p. 43; Vygotsky, 1962).

RESEARCH METHODOLOGY

The study reported in this article sought to answer the following research question:

What is the nature and extent of the learners' 'talk' in a dialogue across implemented lessons on Grade 7 learners' academic achievement in multiplicative word problems?

Research design

A qualitative design was used to illuminate the nature and extent of learners' 'talk' in a dialogue (Creswell, 2014; McMillan & Schumacher, 2010).

Sample

The researcher purposefully selected an experimental group which formed a convenience sample. This sample received a treatment through an intervention, using AWFs as a teaching and learning technique at learner-level in order to obtain detailed information from participants (Creswell, 2014). Two schools participated in this mathematics project within Rekopantswe Area Office in the Montshioa Township in Mafikeng (Mmabatho), Ngaka Modiri Molema District in the North West Province, one of the two was the experimental group.

Data collection instruments

A video with six shots was used in the experimental ($n=42$) class for 6 months on multiplicative word problems concepts such as Rate, Time (Speed), Financial Contexts; Profit and Loss (DBE,2017:20), Solving problems with fractions, mixed and whole numbers, Percentages, Multiplication of Decimals as well as Geometry: Area (2 Ds) were topics covered. Ten AWFs were used as a mediating tool to probe *talk* amongst the learners in arguing their points of view and claims of solutions during the engagement with multiplicative word problems. AWFs were starters, sentence modifiers and connectives that learners used to structure their *talk* during the discussions and argumentations. The teacher started teaching without the use of the AWFs, gradually introduced them (without copies) and eventually learners had copies. Learners worked as a class and in groups of twos or fours.

Validity

For this visual data, the researcher wrote notes in the margins of transcripts as well as recorded general thoughts about the data at this stage. For content validation, the researcher used documents prescribed by the Department of Basic Education, such as policy documents, Grade 7 textbooks together with two Grade 7 Mathematics teachers for the scope and depth of the content topics. The concepts were also confirmed through piloting them in the year before the study was carried out (2016).

DATA ANALYSIS

Vygotsky's analytic tools, the ZPD, mediation and social interaction were used to analyse the video shots on how learners solved word problems and the nature of 'talk' in the classroom. ZPD is determined by independent problem-solving under adult supervision or in collaboration with more capable peer where knowledge sharing between learners and teachers is eminent (Van de Walle, Karp & Bay-Williams, 2013; Vygotsky, 1978, p. 38). Mediation uses language and other ways to exchange semiotics between learners and teachers through an intervention for internal process formulation. Social interaction is the exchange of verbal meaning when learners engage with their teachers in constructing their own understanding (Miller, 2011; Jacobs, Vakalisa & Gawe, 2016; Van de Walle et al., 2013). Two themes - mathematical discussion and mathematical argumentation -

were used at three levels in comparing the results before the intervention (using AWFs), during the intervention and at post-intervention.

ETHICAL ISSUES

Informants were not exposed to risks that were greater than the gains derived in protecting the interest of participants as Letters of informed Consent were sent to parents to request their children's participation. Signed consent forms from learners were received allowing them to be part of the study. Participants entered the research project voluntarily (Bogdan & Biklen, 2007; Okeke & Van Wyk, 2015). Ethical clearance was granted by the university under whose supervision the research was done. Permission was also granted by the Department of Education Area Manager of Rekopantswe Region at Montshioa Township in Mafikeng (Mmabatho), Ngaka Modiri Molema District in the North West Province to carry out the research in the selected schools. Furthermore, the researcher was granted permission by the principals in Rekopantswe Area Office to conduct the study with at least one Grade 7 class.

RESULTS

Mathematical Discussions

Before the intervention (using AWF)

Learners seemed to struggle to express themselves in responding and engaging in mathematical discussions. There was hardly any 'talk' as far as the lesson discussions were concerned, but unwanted noise from the learners. They used the time to discuss to socialise and took too long to start on the work assigned.

During the intervention

Learners were not used to a set up where they sat in small groups for discussion purposes. They ignored instructions and questions asked by the teacher. Learners were fascinated and distracted by the video in the classroom, but later got used to it. Hence, there was time constraint in carrying out the intervention. The researcher introduced AWF which probed learners to *talk* and frame their discussions. Learners freely used the AWFs towards the end of the intervention.

Post-intervention.

Learners engaged more in the discussions in their groups using the AWFs even in the absence of the teacher. They explained how they got the 'area' of a *rectangle* as well correct computations on the chalkboard during boundary crossing. For example, in the concept of 'Multiplication of Decimals' (video 5), learners were able to use frames like: "**To check if my answer is correct, I... would use another operation like; repeated addition for Mr Scullard instead of multiplication.**"

Mathematical Argumentations

Before the intervention (using AWF)

Learners lacked the art needed to make a claim, provide suitable evidence to justify it and logically defend it until a meaningful decision was reached.

During the intervention

The teacher mediated argumentation through the AWFs. Through interactions, learners started produced words, constructions of ideas and solutions to problems, which created the foundation of participants' utterances i.e. in video 4, a few remembered that converting 80% to fractions, is $\frac{80}{100}$.

They also argued well to say in $\frac{80}{100} \times \frac{250}{1}$ litres, we multiply 80 by 250 because in multiplication of fractions, you multiply the numerator by numerator over denominator by denominator.

Post-intervention.

After the teacher allowed the learners to read the word problems and the AWFs, learners engaged in the argumentation process. They freely and confidently offered counterclaims on answers provided and interacted with their peers using academic language (English). In video 5, more learners argued that the operation to be used was "multiplication" and, because, *the fisherman sold*

more kg of fish, that gave more money than R12, 50 and Mr Scullard needed more material for his 4 suits.

DISCUSSION OF RESULTS

Mathematical Discussions

Learners needed more engagement through social interaction and mediation to enhance the 'talk' in the classroom and engage in discussions as evident from grappling to engage before the intervention. According to Venkat (2013), teachers should engage learners in order to understand the rules of solving problems to get to the correct answers. Learners used their social interaction wrongly by not cooperating and making noise at first (Kennewell, 2017). However, towards the end of the intervention, after the teacher had engaged learners in the use of AWFs, the learners' attitude changed for the better. They were cooperative through social interaction, willingly participating in class discussions on concepts mediated by the teacher. They could state their arguments and displayed an understanding of the word problem tasks. These findings resonate with Mercer and Sams' (2006) study conducted in South England where language was used as a mediation tool to enhance discussion skills that learners develop in carrying out mathematical activities (Vygotsky, 1962).

Mathematical argumentation

In answering the research question:

How did the learners' talk in argumentation change across the implemented lessons?

In the absence of the ZPD and mediation, learners struggled at first to display the essence and art needed to make a claim, provide suitable evidence to justify it and logically defend it until a meaningful decision was reached (Sepeng, 2014; Krummheuer, 2007; Ross et al., 2009). During the intervention, the teacher enhanced learners' utterances through social interaction in the use of AWFs (Van de Walle et al., 2009; Reed & Walker, 2014).

CONCLUSIONS AND IMPLICATIONS

Qualitative data analysed suggested that promoting *talk* and *dialogue* in the teaching and learning of multiplicative word problems through the ZPD, mediation and social interaction influenced learners' discussions, argumentation over what was taught. More importantly, this study gives teachers sufficient insight and understanding into the benefits of using AWFs to support dialogue as a teaching technique for word problem-solving across all the major four operations including multiplicative word problem-solving in mathematics classrooms.

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TEACHING PROBLEM-SOLVING IN MATHEMATICS PEDAGOGY: USING A PROTOCOL TO DOCUMENT INSTRUCTION

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Abstract: By using a protocol made of literature-based sets of criteria that address problem solving in mathematics, the research investigated how secondary school teachers engaged with problem-solving as a skill and a process in their instructions. While the National Curriculum Statements and teachers education curricula advocate for instructions that enhance problem-solving skills teachers tend to use pedagogies that are rooted in their daily instructional approaches, habits and beliefs, which hardly address the teaching of mathematics in ways that enhance the skills of problem-solving, relying on procedural approaches that advance memorization, the use of formulas and algorithms instead. Twenty two lessons taught by 4 mathematics teachers were observed and video recorded over a period of 18 months. The findings show that teachers' instructions and the tasks posed in the lessons are mostly procedural and hardly appeal to the skills of problem solving and critical thinking.

Key Words: Problem-solving; critical thinking; procedural and conceptual knowledge

INTRODUCTION

Learning mathematics is about learning how to solve problems using the knowledge and skills of mathematics. The ability to use mathematics effectively to both formulate problems and solve problems is a critical skill that teachers of mathematics from elementary to university should possess. Research has however fallen short on the knowledge of how teachers formulate tasks that engage and enhance learners' problems solving skills. The aim of the research was to investigate how teachers taught the process of problems-solving as well as the skills they required to teach the process and the skills of problem solving in secondary school mathematics. Problem-solving has been identified as an important skill that learners must acquire at an early stage. (Bassarear, 2012). Research further asserts that problem solving has not been realised in classroom practice and remains a challenge for teachers (Sullivan 2006).

The research investigated the following question: *How do secondary school teachers teach the process and the skills of problem solving in mathematics?*

LITERATURE REVIEW

Polya (1973), a pioneer in problem solving, wrote that "[s]olving a problem means finding a way out of a difficulty, a way around an obstacle, attaining an aim that was not immediately understandable." Green & Gilhooly (2005) state that "problem solving in all its manifestations are an activity that structures everyday life in a meaningful way" (p. 347). The South African Department of Education (2001) regards problem-solving as one of the "unique features of learning and teaching mathematics" (p. 18). In other words, problem solving may be defined as the ability to solve "contextually problematic problems wherein the appropriate mathematical models or solution is neither obvious nor indisputable" (Chen, Van Dooren & Verschaffel, 2001, p. 81).

Theoretical framework

This study hinged on the frameworks that evolved around the observation themes (Table 1) that were informed by Schoenfeld’s “Teaching for Robust Understanding in Mathematics (TRU Math) analytic scheme” (Schoenfeld & Floden 2014) and Stein, Grover and Henningsen (1996) five key pedagogical principles model. Schoenfeld (2014) postulates five dimensions of an effective lesson that capture an essential component of “productive mathematics classrooms – classrooms that produce powerful mathematical thinkers” (p. 2). In this framework Schoenfeld and Floden (2014) table *the mathematics*, as the extent to which mathematics discussions are contextualised, conceptually engaging with connections and procedures being core to students’ learning, that is themes A, B and F in this study (Table 1). Others were *Cognitive demands theme F, Access to mathematics content them D, Agency, Authority and identity, and use of assessment themes E and G.*

RESEARCH METHODOLOGY

This was a predominately quantitative research that was a systematic empirical investigation of observable phenomena by use of statistical techniques (Merriam 2009). It involved five secondary school teachers that were purposefully sampled from five schools in a similar social context that offered to take part in the study. Each teacher was requested to plan and teach 6 lessons that were recorded. That gave a total of 24 lessons. The teachers were also given a single task to solve.

Data collection

The data for this research was predominantly made up of the 24 video lessons. A lesson observation schedule (Table 1) that was made up of the predetermined themes A to G was used to document how the teachers taught their lessons in relation to enabling and enhancing problems solving skills development among learners. Schoenfeld’s (2013) points out the complexities of constructing a classroom analysis scheme for empirical use. He describes the many challenges one faces when trying to design a manageable observation scheme and the many revisions it undergoes before a final product is produced. He highlights the contention between classroom observations in theory and in practice.

The observation schedule was developed from a review of aspect of a good mathematics lesson (Anderson 2005; Luneta 2013; Sullivan 2011). Using the postulates of Schoenfeld’s “Teaching for Robust Understanding in Mathematics (TRU Math) analytic scheme” (Schoenfeld & Floden 2014) and Stein et al.’s (1996) model of five key principles for whole class discussions as sign posts, an observation schedule was developed. The schedule was made up of instructional classifications namely Theme A to G- which according to research are instructional competence for teaching mathematics. In order to validate the protocol, further correlation indices based on the instructional rating of experts on a modified Spearman Rank Difference formula were used. Three lessons on DVD were analysed by 16 mathematics experts and the researcher to determine the agreement or disparity in the use of the protocol to classify the teacher’s instructional approach. The average disparity ratio was 0.46, indicating an almost perfect agreement or disagreement in the use of the protocol.

TABLE 1 Research based Observation instrument

Time episode in Minutes	Instructional classification and References PREDETERMINED THEMES	Average score in each Episode (1 – 5) 5 being very good and 1 being poor	Comments (Possible quotes) Examples from successful lesson

0 – 10	A. Teacher's competence in teaching mathematics (good display of content knowledge and pedagogical content knowledge) availing to learners the Mathematics and Access to mathematics content (Schoenfeld & Floden 2014; Sullivan, 2011; Clarke et al. 2002; Darling-Hammond & Ball, 1998; Chen, Van Dooren & Verschaffel, 2011; Stein et al.'s, 1996): <i>Lesson reflected good content knowledge, coherent with connections, careful planning, good examples, good teaching aids, good questioning techniques that appeal to problem solving and critical thinking (Refer to Figure 1). Teacher asks WHY questions</i>	4	(15/20)	The teacher asked the learners where they would like to go if they had money. A good way of introducing currency. Learners discussed what they would need to travel abroad. The teacher asked if they would buy goods abroad using the Rand. More discussion followed. Learners suggested the word <i>converting currency</i> and the teacher then introduced conversions from the Rand to other currencies.
10 – 20		4		
20 – 30		4		
30 - 40		3		
0 – 10	B. Teaching of Mathematics with relevant reference to context and representation (Schoenfeld & Floden 2014; Sullivan, 2011; Anderson, 1993;1991; Stein et al. 1996): <i>Examples from learners' context, learner participation, asking questions, responding to questions</i>	4	(13/20)	Learners: We cannot use the Rand in Spain or Namibia. We need to change it. Teacher: Change to what from where? When can this be done? Who does it? Learners debating
10 – 20		2		
20 – 30		4		
30 - 40		3		
0 – 10	C. Pace of Mathematics teaching and complexity of questions embodied in the instruction (Schoenfeld & Floden 2014; Ingvarson et al. 2004; Stain et al 1996; Anderson, 1993)Learners given sufficient time to assimilate the content covered appropriately and according to learners' needs and cognitive levels. <i>The questions are complex or challenging and not superficial</i>	5	(17/20)	Teacher provided sufficient time for the debate about different currencies, how to convert from the Rand to other currencies. Learners came up with their own method of converting currencies. Learner: We will change each Rand to the Euro: Eu 1 = R11.60 Eu 2 = R23.20 Eu 3 = R 3 * 11.60 = R 34.80 So we multiply every Euro by R11.60. But they will not accept the Rand so we use this information We will use this information
10 – 20		5		
20 – 30		4		
30 – 40		3		
0 – 10	D. Attention to learners, conceptual needs in Mathematics (Schoenfeld & Floden 2014; Darling-Hammond & Ball, 1998; Sullivan, 2011; Stein et al. 1996) <i>Learners given individual attention, active participation encouraged, attends to learners' questions effectively, Agency, authority and Identity , - learners own knowledge of mathematics, The teacher has the ability to identify misconceptions and errors that permeate from learners' attempts at problems (Chen, Van Dooren & Verschaffel, 2011)</i>	2	(12/20)	Teacher provides learners with guidance and lets them discover conversions. Learners: <i>We cannot use the Rand. Let's convert to other currencies such as the Dollar. But Sir, how many Euros in a Rand?</i>
10 – 20		4		
20 – 30		3		
30 – 40		3		
0 – 10	E. Time learners spend on task: Problem solving requires time to both conceptualise, critical think and solve (Schoenfeld & Floden 2014; Sullivan, 2011; Ingvarson et	2	(11/20)	The teacher spent the first session setting a scene for travelling abroad. Teacher discusses how you will buy items abroad using the Rand. All the information you need is on your cards Learners engaged in discussion of how the Rand
10 - 20		3		
20 - 30		3		
30 - 40		3		

	al. 2004; Stein et al. 1996; Anderson, 1993): <i>Learners listen attentively aptivand due to good instructional approach and engaging task, working on problems, discussing and working individually or in groups. According to Anderson (1993) time has to be invested to solve problems</i>		will be used to purchase items abroad. Learner 1: It is not possible, we need money there Learner 2: Where, where, where are we? in our groups we are in Learner 3: We are in an African country? yes! Egypt Learner 4: Is that in Africa? Learner 3: Yes it is. Let us get on with it. Learner 2: But we need to know the money used there
0 – 10	F. Evidence of challenging ideas, none routine tasks and questions. This interrogates learners’ conceptual understanding which is crucial to problem solving and critical thinking (Schoenfeld & Floden 2014, Marchis, 2013,; Stein et al. 1996). <i>Constructive criticism, feedback and encourage learners to generate ideas, challenge each other, listen to the question posed and learners’ responses, teacher solicit learners’ thinking.</i>	4	The teacher divides the learners into groups and hands out cards. On each card are countries where learners are at and need to purchase items. The questions were: Can we use the Rand? Discuss what we can do to buy items we need. What will you buy and how? Discuss and arrive at the answers using the information on the card
10 – 20		3	
20 - 30		4	
30 - 40		4	
		4 (19/20)	
0 – 10	G. Effective use of instructional time. Teacher ensures that the time for effective instruction is well managed and students apply their minds to the problem (Schoenfeld & Floden 2014; Cramer et al. 2009; Cramer & Henry, 2002; Ingaverson et al. 2004; Stein et al 1996;): <i>Sufficient time for content coverage, learners’ participation, evaluation, wrap up and closure</i>	4 3 3 1 (11/20) Total 140	Time not sufficiently used at the end. There wasn’t enough time for a wrap-up. Teacher (Bell goes and learners packing up) Well if there was time we would have tried a few more but try some at home

Data Analysis

Basic descriptive analysis statistics was used to document as well as analyse the data that was collected from the observation schedule. Qualitative content analysis was further used to analyse some of the data from the video recorded lesson with only 4 teachers. The theoretical as well as the substantive focus of the research around teachers’ instruction and problem solving determined the specific type of content analysis approach selected (Merriam, 2009).

RESULTS AND DISCUSSION

The instructional skills (Themes) as documented from the 24 lessons by the researcher and the teachers is displayed in Table 2, ordered from the highest to the lowest mean score. The frequency was the number of lessons the theme scored 2.5 or more out of 5.

Table 2: Descriptive frequency distribution of most prominent instructional skills among teachers (24 Lessons)

Instructional classification (PREDETERMINED THEMES)	Frequency /24	Mean	Standard deviation
Effective use of time	13	3.66	1.376
Teaching within context	11	3.64	1.423
Ensures learners’ time on tasks	10	3.59	1.514

Attending to learners conceptual needs	8	3.55	1.572
Pace and complexity of teaching	7	3.52	1.349
Teachers mathematics competence	6	3.48	1.412
Evidence of challenging ideas	5	3.42	1.567

Most of the lessons were instructionally ineffective as they scored very low on the instructional classification (Themes) in the instrument in Table 1. In Table 2, the evidence of challenging ideas scored the least and the three critical attributes of an effective teachers (Kilpatric et all 2014) of evidence of challenging ideas, mathematical competence and pace and complexity of tasks are in the bottom three. This indicates that teachers’ low content and instructional skills might impact on their ability to teach and present mathematics in ways that enabled learners to acquire the skills of problem solving and critical thinking.

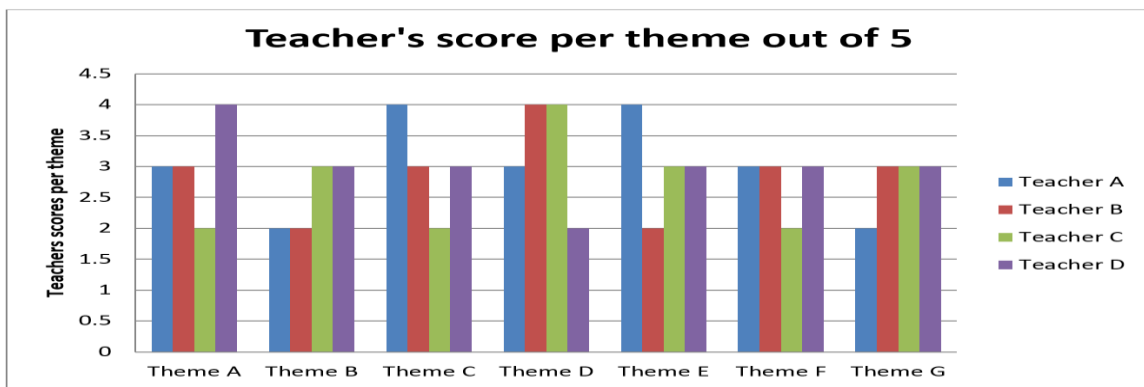


Figure 1: Teachers’ score per theme

Figure 1 shows that the teachers’ thematic evaluations were significantly low. All the teachers were strong on some themes and weak in the other. The evaluation of the teachers’ problems solving skills as well as approaches that address enhancement of critical thinking and problem solving among learners was critically low.

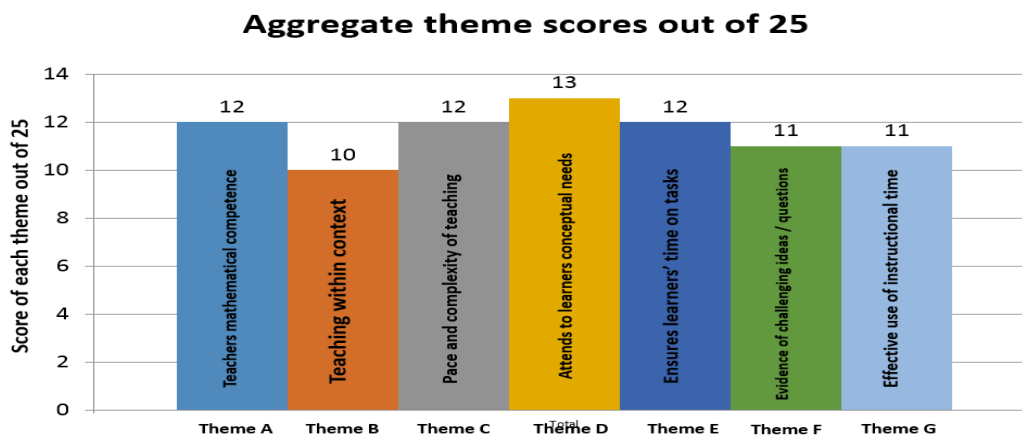


Figure 2: Aggregate teachers’ theme scores out of 25.

It can be seen from Figure 2 that theme D (attention to learners’ mathematical needs) was the most popular theme; followed by themes (A, C and E). The score were however still below the average of 12.5.

Further review of the videos showed that most of the teachers' questions required learners to perform specific procedures as those in most of the mathematics textbooks; directing a learner to a specific algorithmic processes. The results were that these tasks instructionally denuded learners of problems-solving skills (opportunity to conceptualise and analyse a problem, see Table 1). Theme F in the observation schedule (Table 1) requires the teacher to provide evidence of challenging questions. These extract shows that this was not the case.

CONCLUSION

Difficulties in informing teachers the process of problem solving and not merely the skills of problem solving require changing teacher pedagogy. Teacher pedagogy is resilient to changes because it is embedded in ones being, perceptions and values. The skills of problem solving are a byproduct of the process of problem solving. These skills are hardly taught in teacher training courses and it is assumed that preservice teachers will pick them up as they engage with the tasks of teaching (Luneta 2013). Starting with the lesson analysed as an example in Table 1 to the 24 lessons, they mostly scored very low on delivering instructions that equipped learners with the skills of problem solving. The most glaring limitation was the *teachers' competence in teaching mathematics Theme A* and the lack of *evidence of challenging ideas Theme F*. The teachers were not posing challenging questions that required learners to think and engage with the questions at a higher level of thinking.

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TWINNING OF TWO GRADE 11 MATHEMATICS TEACHERS AS A STRATEGY TO IMPROVE LEARNERS' ACADEMIC ACHIEVEMENT IN SOLVING QUADRATIC EQUATIONS

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ABSTRACT: This paper reports the effectiveness of twinning two Grade 11 mathematics teachers in improving learners' academic achievement in solving quadratic equations. Vygotsky's scaffolding as a teaching strategy was used to underpin the study. Pre-test-intervention-post-test design was followed in conducting this study. A pre-test and post-test were administered in both the experimental group and control group in two separate schools in the same day in the same order to avoid the contamination of results. The collected data were quantitatively analysed for the pre-test and post-test results. The findings revealed that twinning in the experimental group had a positive effect on improving learners' academic achievement in solving quadratic equations. The findings indicate that the control group performed significantly different to the experimental group in both the pre-test and post-test results respectively. However, the learners' achievement of the experimental group had an improvement of rank-sum score of after the experiment. The study suggests that twinning can be used in other schools to see if it could yield same results as in this study.

Keywords: twinning; quadratic equations; procedural fluency; conceptual understanding

INTRODUCTION

The twinning of schools has been studied by researchers, including the way in which it affected good professional practice within the European context. It is widely documented that the benefits of twinning are economic, educational, social and political in nature (for example Lock, 2011; Rees, 2003). Nachtigal (1992) argues that most small schools do not have good financial backing, and therefore, require support. The notion of financial constraint is a central reason why schools are twinned or clustered in European countries. Rees (2003) argues that the twinning of schools reduces their salary costs by using one principal to run two schools concurrently so as to avoid the closure of the smaller rural school. Rees and Woodward (1998) concur that costs are reduced in terms of redundancy efforts, as well as the fact that the duplication of equipment and services is eliminated. Other cost savings found in the literature are due to a reduction of the schools' administration requirements, the sharing of speciality materials and equipment, and the sharing of professional development (Lock, 2011; Rees & Woodward, 1998; Rees, 2003). However, as noted earlier, the purpose of twinning in the study reported here is to improve collaboration between the two teachers' own practices to improve Grade 11 learners' academic achievement in solving quadratic equations.

The benefits of twinning were also identified within an educational context, which appeared mostly in guiding this study, as it focused on the benefits that twinning can have, and also consider whether it can change the learners' performance in the under-performing school. The advantages found in the literature mainly examined the learners' learning and the teachers' teaching methods (Lock, 2011; Nachtigal, 1992; Rees & Woodward, 1998; Rees, 2003). Rees (2003) argues that learners benefit more when given the opportunity to interact with other learners from other schools during twinning, further indicating that parental involvement increased, namely in supporting their children by transporting them to and from different schools wherever there is a twinning project. Nevertheless, the issue of parental involvement was not the focus of this study during twinning in the under-performing school.

The teachers also seem to benefit from the twinning process. Rees (2003) indicates the benefits of the teachers in the twinning process as “a regular exchange of ideas, expertise and new knowledge among staff, a renewed teaching staff, and support for creating and testing a restructured/alternative delivery system”. Other researchers agreed that teachers working collaboratively share experiences and ideas during the clustering or twinning process (for example, Lock, 2011; Rees, & Woodward, 1998). The teachers in the two schools shared their experiences, knowledge, ideas and resources in order to see if this might improve the academic performance of learners during twinning. Its purpose was to expose the teacher in the under-performing school to the new practices gained during the process. Galton and Hargreaves (1995) asserted the fact that the teachers have the opportunity to be engaged in the joint planning of activities, where the one teacher can act as a specialist. Hargreaves (2010) indicated that the teachers who work collaboratively are able to transfer professional knowledge more readily and become more efficient in the use of resources. Rees (2003) supported the idea that the smaller schools may access a variety of facilities and materials for development and increase the teachers’ expertise during the twinning process.

As earlier noted, this paper is drawn from the bigger study conducted with two teachers teaching Grade 11 algebra during twinning. This study sought to twin two teachers from two different schools that performed differently in mathematics, thus, one was performing school and the other one was under-performing school. In the bigger study, two teachers who were attached to two schools that performed differently in mathematics, one school was regarded as performing and the other one was regarded as under-performing. During the study, the experiment was performed in the underperforming school where the researchers intended to understand how twinning affected the performance of learners when solving quadratic equations. Some learners in the under-performing school appeared to have challenges in solving quadratic equations in which this problem was picked up during the first phase of the study. This study intended to respond to the following research question: *What is the effect of twinning on improving Grade 11 learners’ academic achievement in solving quadratic equations?*

THEORETICAL PERSPECTIVES

Scaffolding was used as a strategy for teaching quadratic equation with the two teachers from the performing and under-performing schools during twinning. Researchers use the concept of *scaffolding* as a metaphor to describe and explain the role of teachers, or more capable peers, in guiding the learners’ learning and mental development (Hammond, 2002). According to Vygotsky (1978), *scaffolding instruction* is defined as the role of the teacher, and a more capable peer, in providing support to a learner’s development in learning new materials. In addition, scaffolding provides structures by means of which to move a learner to the next level or stage during learning and instruction. The concept of scaffolding thus plays a role in effective learning, by allowing the teachers to use the knowledge gained to assist each individual learner in developing his/her own knowledge and thinking. Scaffolding as a teaching strategy facilitates a learner’s ability to build on prior knowledge, and to internalise new information through the support of the teacher (Van der Stuyf, 2002). The activities provided in scaffolding instruction are just beyond the level of what the learner can do alone (Olson & Pratt, 2000). When one incorporates scaffolding in teaching and learning, one becomes more of a mentor and facilitator of knowledge rather than the dominant content expert to improve academic achievement.

Vygotsky (1978) defines *scaffolding instruction* as the “role of teachers and others in supporting the learner’s development and providing support structures to get to that next stage or level” (Raymond, 2000). However, the effect of scaffolding is not permanent during the learning of new material; it is temporary (Van der Stuyf, 2002). Therefore, the goal of the educator when using scaffolding as a teaching strategy is for the learner to become independent, self-regulating and a problem-solver (Hartman, 2002). This implies that when a learner’s competencies increase independently, or his/her level of understanding is increasing, scaffolding should be gradually decreased, and ultimately withdrawn (Ellis, Worthington & Larkin, n.d.). At that moment, a learner should be able to solve

problems independently, or have mastered the concepts (Chang, Cheng, & Sung, 2002). Twinned teachers who use scaffolding as a teaching strategy aim to enable and assist individual learners who struggle to solve Grade 11 quadratic equation problems, to improve.

Scaffolding is effective when the teachers set tasks that will effectively engage the learners during classroom instruction. Tasks that are clear, manageable and directive enable the learners to take ownership of their own learning or to encourage learner-centeredness. The teacher, in this regard, facilitates learning and is not acting as an expert in the subject. In this study, scaffolding instruction can be effective, where the teacher in the under-performing school observes his counterpart's support of learners through learning activities in algebra.

Scaffolding instructions are suitable to be employed in problem-based learning situations aimed at the learners' mental development (Ngeow & Yoon, 2001). Problem-based learning (PBL) is an educational approach that challenges learners to "learn to learn" (Ngeow and Yoon, 2001). In this PBL, the teacher has to provide the learners with activities that they can solve independently, and know what the learners have to learn to complete a given new task. The teacher then "designs activities which offer just enough of a scaffold for students to overcome this gap in knowledge and skills" (Ngeow and Yoon, 2001). In this study, activities were based on an understanding of the level of the learners' mastery of Grade 11 quadratic equations, in order to overcome the gap between the knowledge and skills by means of scaffolding.

LITERATURE REVIEW

Conceptual understanding is described as a learner's comprehension of mathematical concepts, operations and relations (Kilpatrick et al., 2001; Watson & Sullivan, 2008). Skemp (1976) argued that it is not enough for the learners to merely understand how to perform mathematical tasks (instrumental understanding), but also to know why a particular task is performed (relational understanding). Bransford et al. (1999) and Carpenter and Lehrer (1999) argue that learners who are taught how to develop a conceptual understanding can organise knowledge into a coherent whole, and connect new and old ideas. In this regard the learners would be able to represent their mathematical situations in different ways and know how those representations can be useful for different purposes. The learners could therefore connect mathematical ideas to various representations, and see their similarities and differences in solving quadratic equation problems, and hence mathematical problems.

Kilpatrick et al. (2001) added that, "connections are most useful when they link related concepts and methods in appropriate ways" (p. 141). This is unlike mnemonic techniques, that are learned through rote learning (Hiebert & Wearne, 1986; Kilpatrick, 1985), and which allows the learners to make connections to perform mathematical operations, but does not promote a better understanding of concepts. Kilpatrick et al. (2001) argue that these kinds of connections are not in a better position to promote the acquisition of mathematical proficiency. Skemp (1976) supported Kilpatrick et al. (2001) on mathematical connections that when well-constructed, knowledge is interconnected, so then, when one network of ideas is recalled, it may lead to the another network of ideas to be recalled. In contrast, learners who acquire knowledge with this understanding can generate new knowledge and can solve new and unfamiliar problems (Bransford et al., 1999). It would also appear to the learners that they can connect concepts and procedures and can justify their mathematical ideas, facts and methods. Kilpatrick et al. (2001) further argued that those learners who have an understanding of concepts avoid critical errors in solving mathematical problems.

Kilpatrick et al. (2001) and Watson and Sullivan (2008) refer to *procedural fluency* as the knowledge of procedures, of when and how to use them appropriately, and skills in performing them flexibly, accurately, and efficiently. Watson and Sullivan (2008) preferred the term 'mathematical fluency'. Pegg (2010) presented a clear and cogent argument for the importance of developing fluency in the learners. Pegg (2010) explained that initial processing of information in a working memory, which is of limited capacity, can cause learners to use incorrect procedures to solve problems. Pegg (2010) focused

on the need of teachers developing fluency on procedural knowledge in calculation as a way of reducing the load of working memory, and allowing greater capacity in other mathematical activities as arithmetic and algebra. An example of the way this works is in mathematical language and definitions of mathematical terms (Sullivan, 2011). Sullivan (2011) further argued that if the learners cannot define mathematical terms such as parallel, right angle, index etc., the instructions for using those terms will be confusing and ineffective, because many learners will be trying to gather clues of the terminologies in mathematics. On the other hand, if the learners can readily recall key definitions and facts, these facts can facilitate problem solving and actions.

Procedural fluency seems to be essential if it is coupled with conceptual understanding; Kilpatrick et al. (2001) gave the example of place value, and the meaning of rational numbers, to consolidate the procedural fluency of learners. The National Council of the Teachers of Mathematics (2000, 2014) supported Kilpatrick et al. (2001) on procedural fluency, noting that it should build on a foundation of conceptual understanding, strategic reasoning and problem solving. The differences and similarities between the different methods of calculation could be used when appropriate procedures are learnt when working with rational numbers and place values.

RESEARCH METHODOLOGY

Pre-test-intervention-post-test design was followed to make use of experimental and control groups but do not assign participants to groups (McMillan & Schumacher, 2014). The pre-test and post-test were administered to 84 learners in both the experimental and control groups, but only the experimental group received the treatment. The data generated from the pre-test followed Didis and Erbas's (2014) categories of learners' responses for analysis: *Correct Responses (CR)*, *Incomplete Responses (InC)*, *Incorrect Responses (IR)*, and *Blank Responses (BL)*. To obtain the general view of the performance of the learners, the percentages were calculated using the absolute numbers (Didis & Erbas, 2014). The statistical data are analysed using the Wilcoxon-Rank Sum test for statistics to test for statistical significance. All the variables are not normally distributed (all *p-values* are less than 0.05). The use of a parametric test is warranted due to this normality distribution.

RESULTS AND DISCUSSION

The main purpose of administering the pre-test and post-test in the two groups was to measure the nett improvements/nett decline of the learners' performances in quadratic equations before and after twinning. In particular, the pre-test and post-test aimed at measuring the nett-effect of twinning in the learners' performances. School twinning is a joint commitment of two schools sharing resources for the sake of mutual benefits, and in particular, to promote better school results (Rees, 2003). Lock (2011) argued that school twinning advances school improvement, working together for peer support with an external colleague. This twinning provided the twinned teachers to support learners in the experimental group to develop knowledge of quadratic equations, when they used scaffolding as teaching strategy (Vygotsky, 1978).

The statistical software package that was used to analyse the collected data is Stata V13. The Mann–Whitney *U* test (also called the Mann–Whitney–Wilcoxon (MWW), Wilcoxon rank-sum test, or Wilcoxon–Mann–Whitney test) is defined as a non-parametric test of the null hypothesis, where two samples come from the same population against an alternative hypothesis, especially that a particular population tends to have larger values than the other.

Therefore, we used the Wilcoxon rank-sum test to assess the net effect of twinning, and the interpretation of the results was performed at $\alpha = 0.05$ error rate. Thus, the results were declared significant if $p < 0.05$. The analysis of learner performances per item before and after twinning is given below.

Quadratic Equation Question Items' Results Before and After Twinning

Kilpatrick et al. (2001) and Watson and Sullivan (2008), refer to *procedural fluency* as the knowledge of procedures, of when and how to use them appropriately, and the skill in performing them flexibly, accurately, and efficiently. Learners should acquire procedural knowledge that ought to be supported by conceptual understanding in mathematics (The National Governors' Association Centre for Best Practices and The Council of Chief State School Officers, 2010; NCTM, 2014). Procedural fluency and conceptual understanding acquired by learners have to be influenced by the twinned teachers' support and guidance to learn quadratic equations during scaffolding instructions.

The results for quadratic equation question items indicate that the control group performed significantly differently to the experimental group in the pre-test ($z = 4.051$; $p < 0.001$). In other words, the learners in the control group (rank-sum = 2585.5) over those in the experimental group (rank-sum = 1069.5) were consistently scoring higher marks. The results revealed that the learners in the experimental group appeared to lack the knowledge of solving quadratic equations, quadratic inequalities and simultaneous equations, as well as word-problems, before twinning.

Therefore, the learners in the experimental group appeared to have lacked the skills in performing procedures flexibly, accurately and efficiently (Kilpatrick et al., 2001). The type of support they received from their mathematics teacher when learning quadratic equations could have affected this lack of support and question items appeared to have been beyond the level of what they were expected to perform (Olson & Pratt, 2000). The results showed that the learners in the experimental group lacked conceptual understanding and strategic reasoning in solving those problems. The learners needed to have a deeper and more flexible knowledge of a variety of procedures, along with the ability to make critical judgements about which procedures are appropriate for use in a particular situation (The National Research Council, 2012; The Star, 2005). The results suggest that the support structures learners received appeared to be inadequate when learning quadratic equations (Raymond, 2000).

The same conclusion (as in the pre-testing) was reached in the post-testing, where, for the experimental group, the control group performed significantly better ($z = -4.052$; $p < 0.001$). In other words, the learners in the control group (*rank – sum = 2266*) than in the experimental group (*rank – sum = 1389*) were consistently scoring higher marks. However, the performance of the experimental group had an improved rank-sum score of **319.50**. The results suggested that the conceptual knowledge of finding the factors, solving the inequalities, and solving word-problems of the experimental group improved, as most of the learners knew when and how to use the procedures appropriately, and had the skills of performing those procedures flexibly, accurately and efficiently (Kilpatrick et al., 2001; Watson & Sullivan, 2008). Scaffolding played a major during twinning when supporting learners to understand quadratic equations. The improvement of the results in quadratic equations showed to have been impacted by the use of scaffolding of the twinned teachers during twinning process. The experimental group demonstrated knowledge of concepts when solving quadratic equation problems (The National Research Council, 2012; The Star, 2005). The NCTM (2014) argued that those learners who used the correct procedures in solving problems displayed a foundation of conceptual understanding and reasons why they used those procedures to solve the given problems. The scaffolding used during twinning appeared to have made learners to be independent, self-regulating and problem solver in quadratic equations (Hartman, 2002). This implies that when a learner's competencies increase independently, or his/her level of understanding increases, scaffolding should be gradually decreased, and ultimately withdrawn when solving quadratic equations (Ellis, Worthington & Larkin, n.d.).

CONCLUSION

This paper concentrated on the effect on Grade 11 academic achievement of twinning two mathematics teachers teaching quadratic equations if have improved or not. The findings of the study were analysed comparing the performance of the two schools, control and experimental groups when learners solve quadratic equation problems. Twinning appeared to have improved the results in the

experimental group. The control group performed better as compared to experimental group in both the pre-test and post-test results. However, the experimental group had shown improvement in performance in the post-test which could have been effected by twinning used in this study. The study suggests that twinning can be used in other schools to see if it could yield same results as in this study.

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THE USE OF GUIDED DISCOVERY TEACHING ON THE CONCEPT FUNCTION IN GRADE 11 CLASS IN TWO SOUTH AFRICAN SCHOOLS

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ABSTRACT: This paper reports the outcome of a study on the use of guided discovery teaching on the concept *functions* in grade 11 classrooms in two South African schools. Poor achievement in mathematics in general, and particularly in respect of functions at grade 11 was the motivation for this study. The argument advanced in the study is that the sources of poor achievement among learners vary with contexts. In this case, our view is that teaching methods are the main source of many learning and achievement outcomes. In this study, we use traditional teaching methods as reference to the use of guided discovery teaching method for intervention regarding the learning of functions. Traditional teaching methods are commonly used in the teaching of functions. Hence, their appropriateness as a reference point for the study. The investigation adopts a quasi-experimental design complemented by a qualitative investigation. Data collection involved the use of pencil and paper tests for learners, and semi structured interviews for both learners and teachers. For quantitative data analysis, SPSS software was used while qualitative data analysis was carried out through thematic analysis of text. Although generally the findings revealed little significant differences in the performance between the experimental group and the control group, there is the need to mix methods in teaching different topics to accommodate learning diversity among learners.

Keywords: Functions; guided discovery teaching; modelling; translation; interpretation

INTRODUCTION

The 1995 Third International Mathematics and Science Study (TIMSS-R) in 1999, 2003 and recently TIMSS 2015, show that achievement in school mathematics in South Africa is below the international average. That is, it lags considerably behind other countries. For example, the TIMSS 2015 results indicate that learners in South Africa performed far below the minimum level of competency (Howie, 1999, p. 20; Kanjee, 2004, p. 1; Reddy, 2016). The relatively poor achievement in mathematics particularly in respect of functions may be because of the traditional way of teaching. Traditional teaching methods are known to overemphasise symbolism, manipulative skills and rote memorization of facts rather than developing conceptual understanding and problem solving abilities (Van der Horst & McDonald, 2001, p. 124; Masebe, 2009). Furthermore, under-achievement in mathematics stems from the use of prescriptive approaches in teaching. Prescriptive teaching disregards learners' abilities and disallows them opportunities for self-discovery (Bonnet, Yuill, & Carr, 2017).

The focus of the paper was on learners' conceptualisation and their achievement when both the traditional teaching approaches and the guided discovery teaching methods teachers apply them on functions. According to O'Callaghan (1998, p. 24), guided discovery teaching, connects four competencies, namely, modelling a function, interpreting a function, translating and reifying a function. The argument on using the discovery teaching method is that it has the capacity to enhance a variety of knowledge areas for learners to understand *functions* and related concepts in mathematics. Therefore, the purpose in this study was to explore the effect of discovery teaching on diverse students' conceptualisation and subsequent achievement in *functions*. That is, the study aimed to establish if there were any changes in conceptual understanding and/or effect on their achievement. Thus, the study was an attempt to answer the question: What is the effect of guided discovery teaching on the learners' conceptual understanding and subsequent achievement in their learning of functions?

Additionally, the study was not a comparison of the *effectiveness* of the two methods, rather, how each affected conceptual understanding and effect on achievement because many other factors intervene differently to methods in any teaching and learning situation.

LITERATURE REVIEW

There are many studies in the literature comparing teaching methods. In most instances, these comparisons exclude contexts and/or the methodologies used for such studies. This study illustrates the effect that one method may have in enhancing/inhibiting the quality of learning. That is, methods do not teach; teachers do. How teachers use methods determines the outcomes of the application of the prescripts of the methods concerned. The use of guided-discovery teaching as an intervention tool in enhancing learning in this study stems from its established capacity for developing inquiry and problem solving skills in mathematics learning. Guided discovery teaching approaches engage learners fully in their own learning consequently steeping them in constructivist learning activities (Ndemo, Zindi, & Mtetwa, 2017, p. 76). In guided discovery teaching approach, a teacher leads learners to draw inferences through engaging in activities. Constructivism posits that learners actively construct and reconstruct their own reality in an effort to make sense of their own experiences (Applefield, Huber, & Moallem, 2001).

Meanwhile, traditional ways of teaching provide information that fully explains concepts and procedures that students are required to learn without their active participation in knowledge construction (Kirscher Sweller, & Clarke, 2006, p. 1). In guided discovery mathematics classrooms, the emphasis is on learning than teaching. The teacher designs a sequence of activities to facilitate the discovery of mathematical principles, patterns and relationships (Ndemo, Zindi, & Mtetwa, 2017, p. 76). The teacher's role is minimal and limited to the facilitation of discovery patterns, connections and relationships, thus creating an atmosphere of exploration and sense making (Van de Walle, 2007:34, Ndemo et al., 2017, p. 76). Furthermore, teachers may use models for students' learning and/or better understanding of concepts such as in *functions*. Modelling a *function* involves the transition from a real-life experience to a mathematical representation of that experience (Leinhardt, Zaslavsky, & Stein, 1990). As modelling example, we used a situation of a vendor selling tomatoes. The problem was to identify the best possible way to maximise the profit from the sales of tomatoes to make a decent living. The process entailed the use of variables and a function to form an abstract representation of the quantitative relationships in the vendor's situation (O'Callaghan, 1998, p. 25).

Example 1

Molefe buys a crate of tomatoes from which he gets 10 packets of five (5) in a packet. Find the following:

- The total number of tomatoes in five (5) crates;
- The number of crates Molefe buys if he obtains 150 packets.
- If a crate costs R50 and the monthly rental of the stall is also R50, write the profit per crate of tomatoes as a function of where represents the number of packets of tomatoes sold if each packet sells for R10.

The solutions of the above questions are:

- The number of tomatoes in five crates = $5 \text{ crates} \times 10 \text{ packets / crate} \times 5 \text{ tomatoes / packet} = 250$ tomatoes.
- To obtain 150 packets, Molefe will need to buy three (3) crates of tomatoes.
- The profit per crate is $\text{Profit} = 10x - 50$.

Interpretation: Interpreting a function is the reverse process to its modelling. It gives functions in different representations in terms of real-life applications. This component further subdivides into three most frequently used representations for functions, namely, equations, tables, and graphs (Leinhardt, Zaslavsky & Stein 1990, O'Callaghan, 1998).

Example 2

The following graph describes the motion of a train pulling into a station and off-loading its passengers.

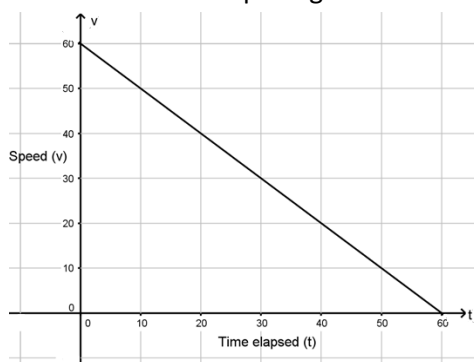


Figure 1: Speed versus time

The graph describes the reduction and calculation of the train’s speed until it finally comes to a stop.

Translation: Translation of a function refers to the ability to move from one representation of a function to another. The five core representational systems that a function can translate among others are contextual, graphical, equations, tabular and language use (O’Callaghan, 1998; Van de Walle, 2004, Leinhardt et al, 1990).

Example 3

Let us suppose that the table below gives the value (V), in rands, of a Hyundai Getz 1.4 GL car for different number of years (t) after its purchase.

Table 1: Number of years and the value in rands

Number of years (t)	Value (V) in rands
0	117600
2	95200
4	72800
6	50400
10	?

The illustration above demonstrates the social application of mathematics and functions in particular. Socially explained concepts are easy to understand as they situate the student in the context s/he understands and/or can associate with its experiences.

THEORETICAL FRAMING OF THE STUDY

Learners encounter the concept *function* in lower grades as functions and graphs. Functions are depicted as relationships between quantities and these quantities are represented as graphs (DoE, 2010). A function is described verbally using words, as a written statement, by an algebraic formula or as a graph (Leinhardt, Zaslavsky, & Stein, 1990; Cadwell, 1996; O’ Callaghan, 1998). Leinhardt et al. (1990) discusses functions from four overlapping constructs of action, situation, variable and focus. The action is the learner’s way activity to determine whether the task carried out is interpretation (e.g. reading, gaining meaning) or construction (e.g. plotting a graph from a data set). Thus, theories that can better explain students’ learning activities of functions must be those considerate of their social interactions. Among such theories is the social constructivism and/or activity theory. Social constructivism is a sociological theory of knowledge according to which human development is socially suited and knowledge is constructed through interaction with others (Muniyappan and Sivakumar, 2018). Activity theory submits that the human mind comes to exist, develops, and can only be understood within the context of meaningful, goal-oriented, socially determined interaction between

human beings and their material environment (Kaptelinin & Nardi, 2018). In representing functions in the three stated competencies of modelling, translating and interpreting a function as stated (O'Callaghan, 1998), students interact socially in meaning construction and engage actively with each other and the tools of modelling information. Through social constructivism, the answers to the question "*What is the effect of guided discovery teaching on the learners' conceptual understanding and achievement of functions*", may be comprehensible. Answers to the quality of students' conceptual understanding and subsequent achievement may be understood in the context of their learning. That is, through social constructivism and/or activity theory, learner' interactions and their learning outcomes through the two teaching approaches may be easily understood and action undertaken to respond to limitations/strengths of the methods.

METHODOLOGY

In this section, we define the research context, explain the research design, state the data collection methods and data analysis.

Research context

The study was conducted among learners and teachers from Grade 11 classes in the Gauteng Province, Tshwane West Region. The sample consisted of 122 Grade 11 learners from two high schools in the region. Schools were selected randomly. Two Grade 11 classes, one with 32 learners and the other with 29 learners from the selected school, were assigned as experimental group. Furthermore, with the assistance of Subject Advisory, the researcher identified a school that was requested to teach the concept of linear functions in the traditional way. From this school, two Grade 11 classes, one with 35 learners and the other with 26 learners, were assigned as the control group. For qualitative investigation, four learners who voluntarily accepted to be interviewed from the experimental group, together with their mathematics teacher were interviewed. The study sought to provide answers to the following problem question:

- What is the effect of guided discovery teaching on the learners' conceptual understanding and achievement of functions

Research design

The research design is quasi-experimental. Quasi-experiments are appropriate for design research studies such as this one. That is, this study links conceptual understanding changes to achievement for two different methods on the same topic. Unlike true experimental designs, quasi-experimental designs are less time-consuming and less costly. The added advantage is that the researcher can select respondents randomly (Leedy & Ormrod, 2005).

Research methods

- Quantitative investigation: A pretest-posttest-control group experimental design was employed. Tests were different but the content was the same.
- Qualitative investigation: Semi-structured interviews were conducted on a teacher and on students who volunteered from the experimental group to get their views, experiences and their preferences regarding the guided discovery teaching approach and learning that took place in their class.

Data collection methods

The following procedure was followed to gather data:

The participating teacher was coached (experimental class teacher) in the application of guided discovery teaching approach to teach functions. The pre-testing for both the control and the experimental groups was conducted before the teaching of the concept. This was to test the conceptualization of functions based on the Grade 10 work. The experimental classes were subjected to guided-discovery teaching of functions for a period of at least three weeks as an intervention, while the control classes followed the traditional approach. The post-test was piloted on four non-

participating learners in a similar nearby school to determine whether questions were up to the required standard of Grade 11. A post-test was administered to both the control and the experimental groups to check improvement as well as progression. Learners who volunteered and a teacher were interviewed after completion of the experimental phase.

Data analysis

Quantitative analysis: Inferential statistics by means of t-tests, effect sizes and analysis of variance were used to analyse the experimental data (Leedy & Ormrod, 2005, p. 274). Qualitative analysis: The researcher grouped information into segments that reflected various aspects of the experience. Divergent perspectives were identified. The researcher used various meanings identified to develop an overall description of the experience (Leedy & Ormrod, 2005, p. 144). All data analysed and interpretations were subjected to literature control.

RESULTS

Interpretation Component

We first look at the analysis of quantitative data in interpretation component between groups for pre-test results. The following Table 2 outlines information on the means of both the experimental and the control groups, p-value for both the experimental and the control groups, t statistic and the effect size and values for other variables for the translation component for both the experimental and the control groups in a pre-test as provided.

Table 2: T-test for groups for interpretation component (Pre-test)

Variable	Group1 = C (Control group) Group2 = E (Experimental group) T-test for Group							
	Mean:C	Std. Dv. C	N:C	t-value: C & E	P C & E	F-ratio Variances C & E	df C & E	P Variances C & E
Interpret Pre-testing	9.50	2.57	61	-0.45	0.27	1.33	120	0.01
	Mean:E	Std. Dv. E	N:E					
	9.70	2.23	61					

d = 0.08

The p-value of approximately 0.01 and the effect size of 0.08 indicate that there is a statistical significant difference but no practically significant difference. We conclude that the differences are not significant between the experimental group and the control with regard to interpret component.

Second, we looked at the analysis of quantitative data in interpretation component within groups. We start first by providing analysis for the translation component within the control group. The following table 3 outlines information on the mean, p-value, t statistic and the effect size amongst others for the interpretation component within the control group for pre-testing and post-testing as provided in Table 3:

Table 3: T-test for interpretation component (control group)

Variable	Group = C T-test for Dependent Samples Marked differences are significant at $p < 0.05000$							
	Mean	Std. Dev.	N	Diff	Std. Dv Diff	t	df	p
Interpret Post-testing	2.66	1.29	61	0.46	1.32	2.718	60	0.008
Interpret Pre-testing	2.19	1.18						

$d = 0.36$

The p-value is less than 0.05 and the effect size is 0.36. This indicates that the differences are significant.

We now look at the analysis of results of the interpretation component within the experimental group. The following Table 4 outlines information on the mean, p-value, t statistic and the effect size amongst others for the translation component within the experimental group for pre-testing and post-testing as provided below.

Table 4: T-test for interpretation component (Experimental group)

Variable	Group = E T-test for Dependent Samples Marked differences are significant at $p < 0.05000$							
	Mean	Std. Dv.	N	Diff	Std. Dv Diff	t	df	p
Interpret Post-testing	3.09	2.20						
Interpret Pre-testing	1.68	1.63	61	1.41	2.74	4.01	60	0.0002

$d = 0.64$

The p-value < 0.05 and the effect size of 0.64 indicate that the differences are possibly practically significant.

Interviews held with learners

Question 1: Can you tell any change that you noticed in the way mathematics was taught in your class since you took the pre-test?

Responses to the question revealed that learners indicated that the teacher introduced the lesson on functions, gave examples to clarify the topic and gave them time and space to go and explore more on the topic.

One of the learners said: “The teacher introduced the new matter by teaching us, followed by several examples to clarify what she has been teaching. Examples are good because you can understand what is going on”. Two learners preferred that at the start of teaching the concept, many examples be given so that they “understand better”. According to them, they understood much better if more examples were given, because they could not follow the lesson if they did not have ideas of what is going on.

Question 2: Did you notice any difference in the way the teacher was teaching or was it just the same?

Responses to the second question indicated that two learners did not pick up any difference while others noted that there was indeed a difference in the teacher’s approach to the topic. One learner

said: "There was some difference because we were given a lot of examples on the topic and given research to do" and the other one said: "There was not much difference to what we are used to, except that she would give us something to research after giving us several examples" .

Question 3: Do you like the way the teacher was teaching in the past three months or so?

There were mixed feelings to the teacher's new approach in response to the third question. Two learners were in favour of it, while other learners were not. This is what one said: "If the teacher continued teaching the way she did, I would benefit, but my peers complained that they could not do a thing without first being guided with examples,"

Question 4: Do you think that the way the teacher was teaching would make you improve your understanding or not?

There were also mixed feelings to the teacher's new approach in response to the fourth question. Two learners were in favour of it, while the other two were not. This is what one said: "I do not like the way she was teaching, because if you do not know what is going on, you cannot do the research we are expected to do on the topic. I like it if she teaches".

Question 5: Did you like the way the teacher was teaching or would you prefer the way s/he was teaching before you took the test?

There were mixed feelings to the teacher's new approach in response to the fifth question. Two learners were in favour of it, while other learners were not. One learner said: "I would like her to teach, because we do not understand that method, and there are no textbooks with answers to the projects we are supposed to do."

FINDINGS AND DISCUSSION

Analysis of quantitative data revealed that the differences among components between the experimental group and the control group in the translation and interpretation components were generally significant. This was the highlight of the experiment, even though the total difference between the two groups in terms of performance was not significant. The performance between the experimental group and the control group was relatively the same. This may be attributed to some of the challenges highlighted by the teacher during the interview and that the experiment was carried out over a limited period. Kieran (1992, p. 408) identified that learners perceive functions as equations only, and cannot relate solutions of equations to values of corresponding functions in graphical solutions. This explains why learners understand functions from procedural rather than structural perspectives. Learners have a better conception of a function if it is in an equation form of computing one value of a variable based on another. Two learners felt that they needed to be taught first before they can work on exercises on function. The impression is that they find it challenging to transfer a word problem to a mathematical statement in symbols, and this is consistent with literature that learners find it difficult to transfer from graphical to algebraic and vice versa (Kieran, 1992, p. 411, Leinhardt et al., 1990). Most algebra textbooks define a function as a relation between two sets so that one member of the domain has only one image. This emphasises the structural rather than the procedural view of functions and learners find it challenging making sense of it because they are inclined to procedural conception of functions (Kieran, 1992, Leinhardt et al, 1990). Two of the learners interviewed hinted that without being taught first they could not comprehend concept functions. The impression is that the teacher requested equations of lines, and they work out ordered pairs and translate the ordered pairs to Cartesian graphs.

CONCLUSION

The performance of the learners in the components of modelling and reification indicated that bringing context to a mathematical concept is still a challenge to how we view mathematics. It is still remote from our day-to-day experiences. To expect learners to make discoveries for themselves proved a serious challenge. Direct instruction appears to be a preferred approach to teach functions. The view is

that functions are associated only with equations of lines, and they work out ordered pairs and translate the ordered pairs to Cartesian graphs. They apparently do not relate to some real life concepts. This view is apparent in the significant differences in the performances in the translation and interpretation components. The study highlights the need to bring context to teaching mathematics and science.

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APPLYING THE RASCH MODEL TO VALIDATE A TEST INSTRUMENT OF STUDENTS' RATIONAL NUMBER COGNITION

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ABSTRACT: The rational number knowledge of student teachers, in particular, the addition and subtraction of fractions, is the focus of this paper. In-service teachers do not have it easy with teaching fractions either. This cycle is expected to be discontinued when the new teachers are being prepared to go into the service. It was necessary to identify gaps this cohort brought into the Foundation Phase programme. An instrument comprising multiple choice, short answer, and constructed response formats was designed to test their conceptual and procedural understanding of rational numbers. Application of the Rasch model allowed the validation of the mathematics test construction process, the items selection and the parameter measures. Strategies for resolving these issues are discussed in this paper. The validation of the instrument was achieved by making explicit the expected responses according to the model versus actual responses by the students. The test items showed good fit to the model, however response dependency and high residual correlation within sets of items was detected.

Keywords: Rasch measurement model; rational numbers; foundation phase student teachers; validity

1. INTRODUCTION

The rational number knowledge of student teachers, in particular, the addition and subtraction of fractions, is the focus of this paper. In-service teachers do not have it easy with teaching fractions either. This cycle is expected to be discontinued when the new teachers are being prepared to go into the service. It was necessary to identify gaps this cohort brought into the Foundation Phase programme. The aim of this study was to gauge the level of students' cognitive understanding of rational numbers and ascertain the validity of the instrument that was used to elicit their mathematical cognition. All the participants (n=117) admitted into the Foundation Phase teacher training programme were tested on 93 items that solicited both conceptual and procedural understanding, with items comprising multiple choice, short answer and constructed response formats.

Application of the Rasch model enabled a finer analysis of the test construct, the individual item and person measures, and the overall test functioning through making explicit the expected responses according to the model versus the actual responses by the students (Rasch, 1960/1980). In addition, the test as a whole was investigated for properties that are requirements of valid measurement such as the construct local independence, which means that each item works independently of the other items.

This paper reports on how students performed when addition and subtraction involved fractions. In this paper we describe relevant aspects of the main study but hinge primarily on the validation of the instrument. The sub questions on whether the test provide valid measures of student proficiency as well as it can be improved for greater efficiency of administration, and estimating student proficiency are answered. The aims of the immediate analyses were to:

- evaluate the assessment tool in terms of fit to the model, both item and person fit, thereby checking whether the tool was appropriate for the students,
- provide detailed description of the items in relation to the students taking the test

In this paper we report primarily on the validity and reliability of the assessment tool as analysed through the Rasch model which applied both the dichotomous and partial credit model. The processes of analysis and refinement, and the final outcome of this cycle are described. As this test was used as a

preliminary diagnostic instrument, we see ongoing cycles of refinement in the interests of informing the teaching of mathematics on fractions-decimals-percentages to pre-service teachers.

LITERATURE REVIEW – FRACTIONS ASSESSMENT AND MEASUREMENT

Stiggins and Chappuis (2005) explained that assessment must be guided by a clear purpose and it must accurately reflect the learning expectations. Wiliam (2011) affirms that a method of assessments must be capable of reflecting the intended target and also act as a tool for teaching proficiency. In an attempt to clarify the assessment, how it was conducted and its purpose, we endeavour to provide the justification for the exercise. It was critical to ensure that certain conditions were satisfied in order to safeguard the effectiveness of the assessment as well as the validity of the test items. These were the core intentions of the assessment in this research and therefore the validation of the test as a whole and each item was critical and appropriate.

Wright and Stone (1979) suggest four important requirements for a valid measurement. For valid measurement within the social sciences, as well as with the physical sciences, a theoretical investigation of the construct is required in order to define clearly what is to be tested. The next requirements are to outline the interrelationships between component parts of the construct as well as the alignment of items that will operationalise the construct in its complexity, and provide the teacher with evidence of misconceptions that would need to be addressed in class. A final phase is the post hoc verification of the functioning of the test as a whole and of the individual items in the test. This paper reports on the appropriateness of the instrument designed to test the students' levels of understanding and conceptual knowledge as they entered the teacher education programme at a university.

The learning and teaching of rational number concepts are particularly complex processes, in that there are at least two distinguishing features of rational numbers argue Vamvakoussi and Vosniadou (2007, 2010). The first is that for each point on a number line, for example $\frac{1}{2}$, there are infinite representations that is $\frac{2}{4}$, $\frac{3}{6}$, $\frac{4}{8}$ etc. The second feature is that between any two points on the number line there are infinitely many numbers (Vamvakoussi & Vosniadou, 2007, 2010). Given this complexity, the operations on rational number, addition, subtraction, multiplication and division do not easily lend themselves to procedures that may previously have been learned when working with whole numbers (Harvey, 2011; Pantziara & Philippou, 2012). This conceptual complexity generates misconceptions and associated errors which may be interpreted as lack of conceptual understanding (Luneta, 2015). Research shows that in most cases both teachers and learners appear to have instrumental understanding of fractions, but do not really know why the procedures are used (Post, Harel, Behr, & Lesh, 1991). In addition to the conceptual-procedural distinction, students tend to develop conceptual schemes and information processing capacities to master fractions, decimals and percentage concepts individually as well as in the interaction with each other (Kieren, 1980). The educational aim however is for students to have a combined and balanced ability to follow a procedure with conceptual or relational understanding (Zhou, 2011).

Studies (Dempster, 2006, 2007; Long, 2007) on assessment and their use in South Africa have argued that test item profiling can enable teachers to fine tune their instruction in ways that enable effective teaching and learning. It is asserted further that the data from assessment can be used for formative, development and diagnostic purposes (Shalem, Sapire & Sorto, 2014).

RESEARCH DESIGN (PARTICIPANTS, MEASURES AND MODELS)

The sample was all the 117 students that were admitted into the Foundation Phase teacher training programme. The pretest comprised 93 items that was designed to elicit prior knowledge at the beginning of the academic year. The assessment tool worked as a diagnostic assessment test that sought to identify misconceptions and associated errors the students made when responding to the test items as deemed suitable by McMillan, Cohen, Abrams, Cauley, Pannozzo, and Hearn, (2010).

The items were primarily informed by the conceptual knowledge that could be identified according to the following requirements:

- The items required mostly procedural understanding, or mostly conceptual understanding
- The items included fraction, decimal and percentage representations
- Items were generated with the specific purpose of evoking misconceptions. The items were comprehensive, covering most concepts and sub concepts within the three representational systems, fractions, decimal fractions and percentages.
- The format of the test items types included multiple-choice items, short-answer as well as extended-response items.

The reason for such a comprehensive selection of items was that the mathematics lecturers needed to know beforehand what difficulties and misconceptions the students displayed and brought into their second semester mathematics class. Also, at the time of setting the items, the lecturers were not sure just exactly where the difficulties would emerge from.

The Rasch model was applied in this study in order to confirm or challenge the theoretical base, to check the validity of the instrument, and to quantify the students' cognition of rational number concepts. The hypothesis was to explore the extent to which the assessment tool functioned according to measurement principles. The Rasch model provided information on where the differences in student responses occurred, possible explanations could be inferred, the possible explanations presented, as well as providing pointers for the refinement of the test instrument. The reason being that the Rasch model does not only provided the researcher with the validity and reliability of the test items but also specific aspects for further improvement (Bond & Fox, 2015). The choice of the Rasch model is premised on the particular strength implicit in the model, which aligns both item and person parameter on the same scale (Wei, Liu, & Jia 2014). A good test needs to separate individual's proficiency level as well as item difficulty. The proficiency of the student should not be dependent on the difficulty of the test. The model developed by Rasch fulfilled these two conditions (Andrich, 2006).

RESULTS - INDIVIDUAL ITEMS AND DEPENDENCE

As the Rasch model enables the researcher to predict how a student in a particular location will perform against an item, at, below or above their own location on the scale. The Rasch model further predicts that a student of higher proficiency should be able to answer all the items correctly that a person of lower proficiency answers correctly. Likewise, easier items should be answered correctly by low proficiency learners, and also by moderate proficiency and higher proficiency learners.

In the study each individual test item was validated in the following manner. The ideal test instrument is comprised of items that all contribute information to the measurement of the intended construct, and that no two items should exactly contribute the same information. The relationship between a question item and students location is under discussion.

Item 20, a relatively easy item, with an item location of about 0.316 logits, is presented. Figure 1 depicts the characteristic curve of item 20 with the line A (low proficiency, located at -2.159) and F (high proficiency, located at 1.733) representing two of the students under discussion as part of the six question items (see figure 2 and table 1). The student located at F has 80% chance of answering this item correctly, however the student located at A, has about 9% of providing a correct response. The model predicted this outcome, which is not to say that the low proficient student would not answer a very difficult item correctly, but this outcome was highly likely to be realised. A student at location 0.316 (exactly the same location with item 20) has a 50% chance to offer a correct response to this question (dotted lines in figure 2).

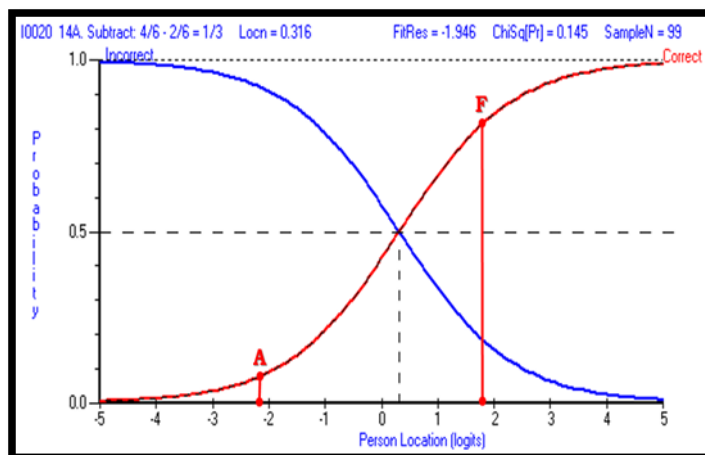


Figure 1: Item 20 (14A) - Item characteristic curve (the easiest in this group)

Figure 2 displays students' examples of misconceptions and associated errors of whole number bias. The students brought the addition and subtraction in working with whole numbers to addition and subtraction of fractions treating the numerator and denominator as whole numbers (Zhou, 2011). The errors are consistent in addition and subtraction in how this misconception is perpetuated where the student either adds/subtracts or multiplies the denominators with no use of equivalent fractions in the solution (Brown & Quinn, 2006).

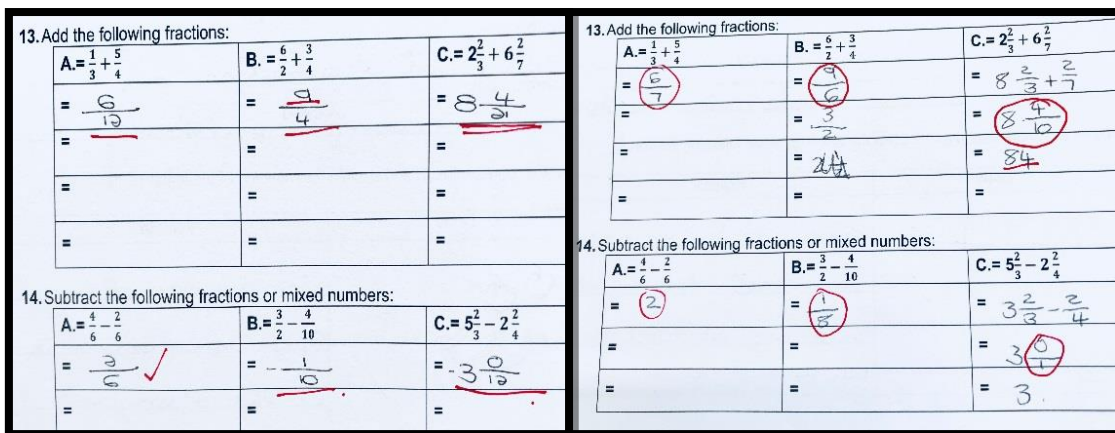


Figure 2: examples of responses to questions 13 and 14 for discussion in Table 1

These examples of two students' responses revealed differing misconceptions that transfer across addition and subtraction the way the students dealt with numerators and denominators per student. A big majority (76% and 66%) of the students were not able to get the correct answer in the addition and subtraction of fractions (13A to 13C, 14A to 14C) respectively (Maseko, 2015). A closer Rasch analysis of these individual test items in this set of questions revealed that the item that proved most difficult was 13C. the question wanted the students to work with mixed fractions, then the conversion to improper fraction, then get lowest common denominator, only add the equivalent fractions, then convert back to mixed fraction, simplify if necessary (the sequence of the steps is not linear though crucial but maybe be omitted on paper record). We briefly report on six students against these six related questions on addition and subtraction, in relation to their locations to illustrate the relationship of person proficiency to item difficulty.

Table 1: Six students' performance on six items

Weakest to strongest student	Low proficiency		Moderate proficiency		High proficiency	
Easiest to difficult item /	-2.159	-2.143	-0.032	-0.032	1.716	1.733
	(A)	(B)	(C)	(D)	(E)	(F)
Item 20 (location 0.316) [$14A = \frac{4}{5} - \frac{2}{6}$]	0	0	1	0	1	1
Item 21 (location 1.170) [$14B = \frac{3}{2} - \frac{4}{10}$]	0	0	0	0	1	1
Item 17 (location 1.375) [$13A = \frac{1}{3} + \frac{5}{4}$]	0	0	0	0	1	1
Item 18 (location 1.577) [$13B = \frac{6}{2} + \frac{3}{4}$]	0	0	1	1	1	1
Item 22 (location 1.802) [$14C = 5\frac{2}{3} - 2\frac{2}{4}$]	0	0	1	0	1	1
Item 19 (location 2.385) [$13C = 2\frac{2}{3} + 6\frac{2}{7}$]	0	0	1	0	1	0

Item 20 is the easiest whilst item 19 is the most difficult in this table and the six items are arranged from easiest down to the most difficult. The students, as well, are arranged from left to right according to their Rasch determined proficiency levels. The weakest students A (location -2.159) and B (location -2.143) struggled with all the six questions as predicted according to the locations of all items. We would not expect these students at these locations to have any chance to offer a correct answer to these questions. Of the two students in the moderate category, both students C and D (located -0.032) had differing responses to this set of questions. Student C responded with a correct answer in four instances whilst the second one (student D) offered incorrect answers in five cases. Both students were able to get correct answer to item 18 which had related denominators. Lastly, the two students located in the high proficiency category are located at 1.716 logits (E), and 1.733 logits (F) respectively, are very close to each other and could also provide an easier comparison. Both students are located to the left of the item (1.733 against 2.385) are then expected to have an even less than 50% to get the correct answer. It is no wonder that this student pair was very close to a perfect score except for the most difficult of six items. The cognitive demand required the students to connect their knowledge schemes as explained earlier. Applying the Rasch model to a data set is essentially testing a hypothesis that invariant measurement has been achieved with some anomalies in terms of items dependence.

LOCAL INDEPENDENCE INFLUENCES

The Rasch model offers a further check on the validity of the test appealed to an investigation of local independence. In any test, one expects that each item would contribute some information to the test construct. On the other hand, there may be cases where there is response dependency, where answering a second item correctly is dependent on answering the previous item correctly. Another threat to validity of the construct is where there are too many items targeting one aspect of the construct, for example, five items asking for similar knowledge. In such a case the student who knows the concept is unduly advantaged, while a student who does not know the concept is unduly disadvantaged. High residual correlations between items can be resolved by forming a subset, essentially a super-item, where the two items contribute to the score (Andrich & Kreiner, 2010).

As stated earlier, it is expected in any construction of a test that each question contributes independent information about the construct, a quality labelled as local independence. The two threats to local independence are multidimensionality and response dependence (Hagquist, Bruce, & Gustavsson, 2009). In this instrument analysis, we checked the residual correlations of the items and found high correlations, both positively correlated sets of items, and negative correlations. The implications of such a threat to local independence is that there are many items contributing the same information. A resolution of this situation is to create subtests of items that are highly correlated, by investigating both the item context and the statistics it conveys. 18 subtests were created and were then checked for ordered or disordered thresholds. For illustrative purposes question 6 is discussed.

Question 6 required students to 6a draw a representation and 6b explain the meaning of $\frac{2}{5}$ fraction. Item 6a and 6b were subsumed into a subtest. The subtest was structured in such a way that instead of having two items which were highly correlated, there was one partial credit item, for which the student could obtain a zero (0), for non-correct, a one (1) for one of the two questions correct or a two (2). On investigating the subtest and the partial credit item, it was observed that the common response was either non-correct, or both correct. The middle category for which one mark awarded was almost redundant. The answer was then to re-score the item as a dichotomous item and the resulting curve to show a better understandable distribution (figure 3).

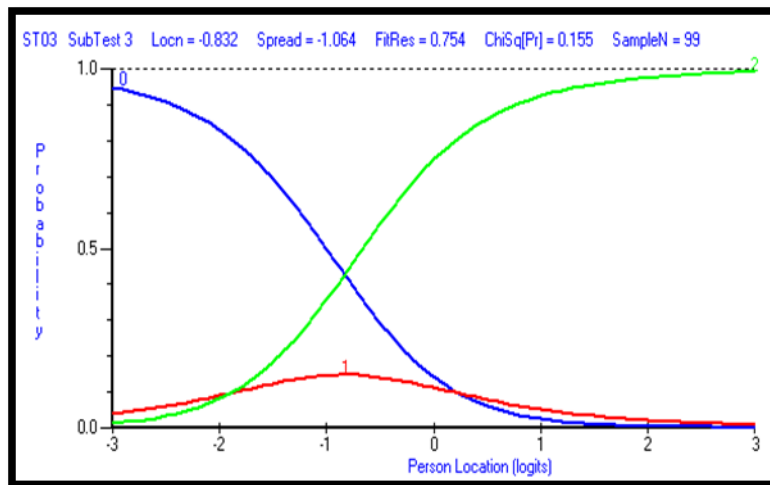


Figure 3: subtest 3 (question 6) – re-scored responses curve

After the investigation of specific subsets the test as a whole was reviewed in order to ascertain from a conceptual perspective which items could reasonably be subsumed into subtests, if necessary. The subtests that functioned as expected were retained, but those whose categories that were, for some conceptual reason, not functioning according to measurement principles the rescoring of the items was to some extent affected and therefore left out.

Table 2 shows the refined test person mean, -0.4172 in the initial analysis, moved to be closer to zero, 0.099, implying that by resolving some of the test issues, the targeting of the test to these students was found that the range of proficiency was narrower.

Table 2: Summary statistics of Fractions, Decimals and Percentages - comparing the initial and final analyses

Initial analysis		Final analysis	
Item Mean	0	Item Mean	0
Item Standard Deviation	1.6302	Item Standard Deviation	1.4933
Person Mean	-0.4172	Person Mean	0.099
Person Standard Deviation	0.9442	Person Standard Deviation	0.7580
Person Separation Index (PSI)	0.90887	Person Separation Index (PSI)	0.86062
Power of Analysis of Fit	Excellent	Power of Analysis of Fit	Excellent

The outcome after this final analysis was a test with 50 items, 22 of which were multiple choice and 28 were constructed response formats. Figure 4 appears more compact in location distribution of both the test items difficulty and students' proficiency levels. The easiest of the items (ST031) is far easiest and

away from the next easy items by almost 2.5 points. There are two items (ST17 and ST08) that were difficult to all the students.

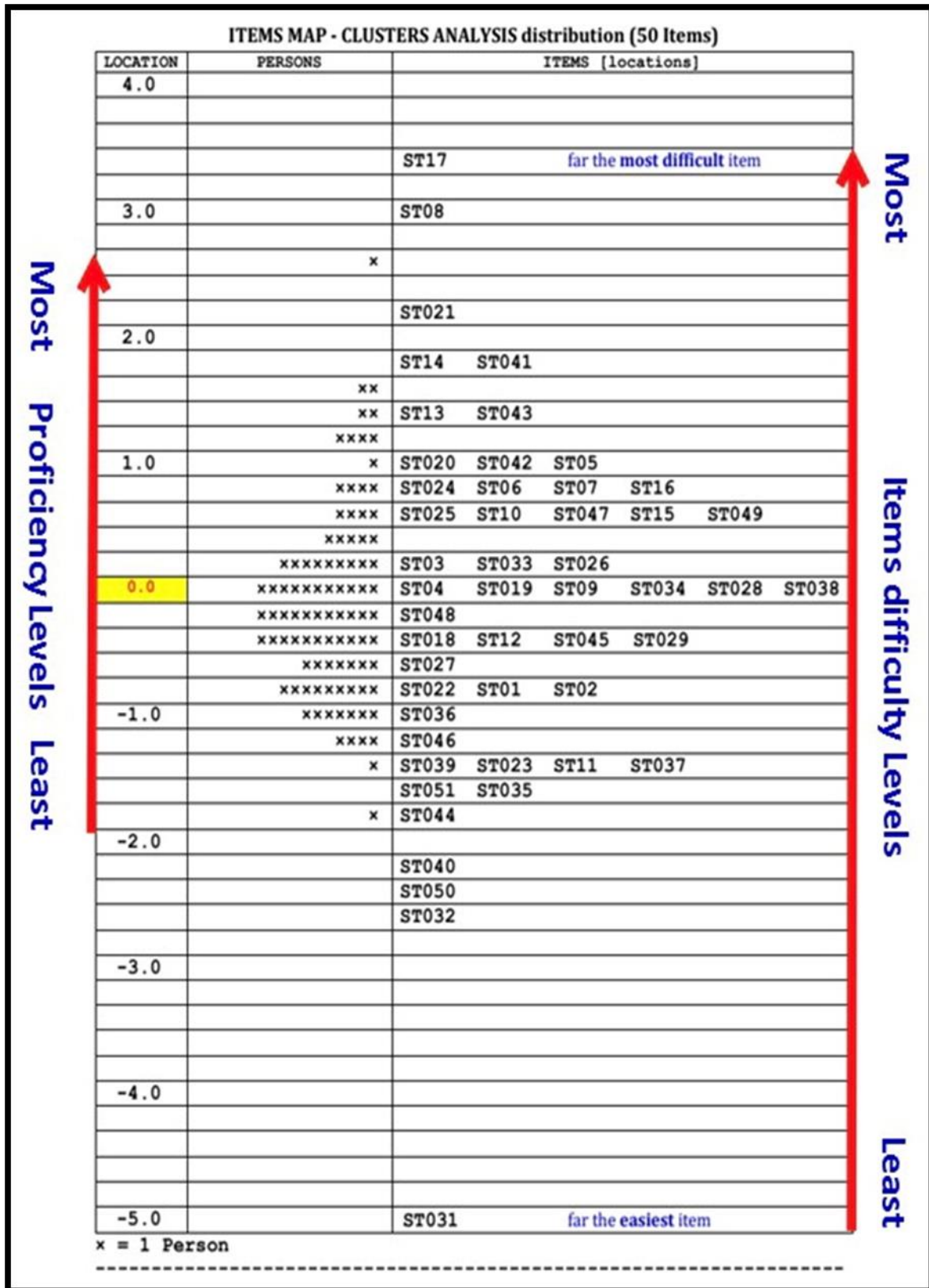


Figure 4: Revised Person-item map

SUMMARY AND IMPLICATIONS

As stated in the introduction, this paper forms part of a larger study into the student cognition of rational number, fractions, decimals, and percent. The purpose of the investigation was to inform the lecturers of the current status of student knowledge of fractions and how best to address the misconceptions during instruction. This study is in line with McMillan et al., (2010), who proposed that formative assessment, the appropriate identification of student weaknesses, monitoring progress, enabling the provision of specific feedback, as well as including instructional correctives to address weaknesses, is critical to teaching. The benefits of assessing the students' performance, monitoring their progress, providing feedback and changing instruction to include addressing weaknesses, cannot be overstated. Applying a diagnostic test at the beginning of a course informs instruction. The critical point to note is that the test items must be reliable and valid in such a way that they are able to provide a comprehensive view of the students' ability and learning outcomes.

The Rasch model was applied in this study in order to confirm or challenge the theoretical base, to check the validity of the instrument, and to quantify the students' cognition of rational number concepts.

The application of the Rasch measurement model enabled a sharper understanding of these students in terms of proficiency within a set of items at their level. The outcome of the data as fitting the model, the high person separation index and the appropriate targeting confirmed that the theoretical work had supported the design of a well-functioning instrument.

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EXPLORING GEOMETRIC PATTERN TASKS TO ENHANCE GRADE 8 LEARNERS' ALGEBRAIC REASONING

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ABSTRACT: This paper chronicles how learners' algebraic reasoning can be promoted through the use of geometric pattern tasks in an action learning environment. Geometric patterns as the object of learning and application of algebraic reasoning pose a demanding encounter to most of the learners in grade 8. This qualitative case study used classroom observations and semi-structured interviews to explore how geometric pattern tasks can be used to improve learners' algebraic reasoning. This paper reports specifically on classroom observations done on how 22 grade 8 learners in one rural school learnt geometric and numeric patterns. Two learners were then interviewed on the basis of the illustrations displayed on how they constructed patterns and extended them for generalisation. Findings revealed that when numeric and geometric patterns are treated as separate entities, co-variation thinking is not supported. Therefore, learners could not verify and make conjectures that check the validity of the separated patterns. We therefore, recommend that teaching should consider variation and invariance within and among patterns tasks in order to support students to discover structure that relates patterns, generalise about numeric patterns through geometric patterns, predict, prove and solve problems on patterns.

Keywords: Geometric patterns; numeric patterns; algebraic reasoning; variation theory; co-variation

INTRODUCTION

Geometric patterns refer to visual cues that can be organised and translated to numeric sequences (NCTM, 2000). Visual cues are fundamental to algebraic reasoning, which is, thinking that supports comprehension of numbers. Further, visual cues enhance computational skills through learning that proceeds from concrete to abstract reasoning, that promotes working from visual patterns to numeric patterns. According to Curriculum Assessment Policy Statement (CAPS), algebraic reasoning skills in relation to pattern tasks in grade 8 entail (i) investigation of relationships of numeric and geometric patterns by representing them in physical and diagrammatical form; (ii) promotion of learners' own creation, description and justification of general rules for observed relationships between numbers in their own words (DBE, 2012). Relationships refer to common cues that are inherent in numerical and geometric patterns that can be represented using words, tables, graphs, and symbols. Geometric patterns as the object of learning and application of algebraic reasoning pose a demanding encounter to most of the learners in grade 8. Teachers face a challenge of applying teaching strategies that enable learners to learn by predicting numeric representations using geometric patterns. According to Smith, Hillen and Catania (2007) geometric pattern tasks are useful tools that can support learners to develop algebraic reasoning. In addition, Smith et. al (2007) highlight that geometric tasks are essential in assisting learners to participate in creating geometric patterns and in this sense learners are able to observe how patterns develop. This study aimed to explore issues of classroom practice in geometric patterns, extrapolate on them for the better development of learners' meaningful understanding of patterns.

While noting the realities faced by learners in the rural schools visited during the study, Wilmot & Schafer (2015) argue that a creative classroom should ideally provide opportunities for learners to ask questions, generate their own ideas, draw conclusions, collaborate and co-construct their conceptual understanding. In light of Wilmot and Schafer's (2015) motivation, this study harnesses action learning to create an environment where students are active participants. Most of the textbooks used as teaching and learning resources in grade 8 mathematics classrooms, require learners to provide rules

of geometric patterns already drawn for them. However, representation is part of a learning process since it guides learners to identify key features of the learning object to promote reasoning. It was with this view that the observed practice allowed learners to create their own pattern in an action learning environment, after which they were required to give explanations of their chosen designs.

In the Mt Ayliff area where this study was conducted, very often geometric symbols are used as a mark to identify each of the flock of sheep that belong to a certain home. In this sense student get exposure to geometric symbols out of the classroom context. Kumpulainen, Mikkola, & Jaatinen (2013) assert that it is challenging or even impossible to promote the twenty-first-century learning requirements, such as critical thinking and problem solving, collaboration and communication, creativity, new literacy and media skills in an educational environment that is restricted in specific space and time, and is purely teacher-led and controlled. The classroom environments and instructional designs in the schools visited were teacher dominated and fell short of helping learners to apply pre-knowledge and develop fluency required to perform cognitive tasks in mathematics. This fluency is an essential aspect of learning in recognising geometric and numeric patterns. The purpose of this article is to use semi-structured interviews and classroom observations to address the research question: How can geometric pattern tasks be used to improve learners' mathematics understanding? We will not repeat considerable evidence pointing to the challenges experienced by learners when dealing with patterns within South African Schools. Such evidence is available in abundance (Stuurman, 2014; Jones, 2000; Siyepu & Mtonjeni, 2014). What is lacking in the available literature are the new explanations of how the use of geometric pattern tasks in an action learning environment can promote and improve learners' algebraic reasoning.

In the first part of this paper, we provide evidence for algebraic reasoning in the representation of geometric patterns. Next, we will zoom into geometric patterns to illustrate learners' cognitive process in algebra. Finally, we will conclude by evaluating the use of contextual factors relevant to learners' environment to improve learners' algebraic reasoning.

LITERATURE REVIEW

Smith (2016) asserts that the promotion of algebraic reasoning in the classroom involves incorporating conjecture, argumentation, and generalisation in purposeful ways so that learners consider arguments as ways to build reliable knowledge. For example, algebraic reasoning can be used to help learners to recognise patterns by describing them verbally or algebraically such that they create arguments that will assist to validate their conjectures and generalisations. Sometimes geometric patterns are known as visual growing patterns, or pictorial growth patterns (Billings, Tiedt, and Slater, 2008), which involve the use of figural objects (Rivera 2007). In essence, geometric patterns are basic units for all designs. A repeated fashion that consists of arranged lines and geometric figures, such as triangles, circles and squares forms a geometric pattern in mathematics. Art and architecture together with many man-made structures, like buildings and bridges are some structures in which geometric patterns can be identified. Geometric patterns also extend to represent some aspect of culture such as the history and background of the civilisation and its accomplishments. Some major pattern types are seen in the different ways in which the Nguni huts are colored and decorated. For example, the Ndebele huts paintings use different colors and shapes for their designs while the Xhosa huts would use only one color with a straight mud belt at the bottom. Teachers should then use the visual cues available in the learners' immediate environment to enhance their conjecturing and validation skills.

Researchers, (MacGregor & Stacey, 1995; Wilkie & Clarke, 2014) note that teachers usually encourage learners to describe the features of a geometric pattern verbally first and then express those algebraically. This extension of a growing pattern by identification of its physical structure, features that change, and features that remain the same is known as figural reasoning (Wilkie & Clarke 2014). Contrary, Smith (2016) argues that learners should first be taught, how to compare two pattern tasks then consider how they are the same and how they are different in order for them to engage in algebraic reasoning. However, through the activities conducted with the learners in this study, action

learning was promoted. Learners were issued with match sticks to create their own chosen geometric patterns. In this sense, learners' cognitive processes were illustrated through the physical structures constructed as evidence of engaging algebraic reasoning skills. They practically represented some geometric patterns using match sticks and were able to relate how they constructed them and their expectations of a finished product.

Vogel (2005) suggests that taking advantage of patterns is typical of our everyday experience as well as our mathematical thinking and learning. The author further claims that the practice of good interaction with patterns supports not only the active learning of mathematics but also a deeper understanding of the world in general. Learners utilised match sticks to identify, describe, extend, compare, represent, and created their own patterns. By using the real life contexts in pattern development, learners were guided to use patterns not just as process elements but also as content elements of mathematical thinking and learning.

THEORETICAL FRAMEWORK

According to variation theory, learning is characterised by noticing variation and invariance in the object of learning, further, being able to discern diverse features of what is being learned (Kullberg, Kempe & Marton, 2017). An object of learning or learning object is an essential term used in the variation theory. It refers to the content that must be learned, or the object that learning is directed to. The process of variation is defined in terms of four stages, that is, contrast, separate, generalise and fuse (Marton, 2009; Leung, 2012; Ling & Marton, 2012; Mhlolo, 2013). According to this theory, a learner understands a concept if he/she can: **Contrast** - be aware and pre-suppose that to know what something is, one has to know what it is not, that is, to discern or learn whether something satisfies a certain condition or not (Leung, 2012); **Separate**- focus on certain features that are critical and draw learners' attention selectively to the critical aspects of the object of learning, **Generalise**- apply conjecture and verification skills that check the validity of a detached pattern, that is, a pattern that separates the particular from the general; and ultimately **Fuse** - connect variation experiences gained in previous and present interactions (Leung, 2012).

Teaching with variation according to Kullberg et al. (2017) implies focusing on critical features of the learning object; identify differing levels of conception; and identify from conceptions the main ideas that need to be invariant and variant. Kullberg et al. (2017) argue that in mathematics, teachers can assist students to engage in mathematical structures by applying variation and invariance when teaching through examples. In addition, Kullberg et al. (2017), outline that essentially, if students do not discern the necessary aspects, learning might not occur. Similarly, Lo (2012) argue that learning an object is not possible if learners are unable to discern from specific to general in relation to the object of learning.

METHODOLOGY

This paper reports on the third phase of a three-year longitudinal study conducted in fifteen rural situated schools in the Mt Ayliff district of the Eastern Cape in South Africa. The rationale for targeting secondary schools located in a rural area emanates from the research findings that have persistently linked poor performance in mathematics with disadvantaged socioeconomic communities, such as those characterising schools in rural settlements of Mt Ayliff. This study aimed to investigate issues of classroom practice in mathematics, extrapolate and/or improve on them for the better development of learners' meaningful understanding of patterns. After the challenges faced by learners in understanding grade 8 mathematics through pre-evaluation tests administered prior to this study, workshops were held as a form of intervention with the teachers. This paper reports specifically on classroom observations done on how 22 grade 8 learners in one rural school learnt geometric and numeric patterns. After the observations, three learners were interviewed on how they developed their representations of geometric patterns on the basis of their displayed interesting work. This was a qualitative case study located within an interpretive paradigm which seeks to understand the situation from the perspective of the participants (Ary, Jacobs & Razavieh, 2002).


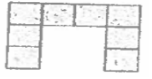
Miles and Huberman's (1994) technique was adopted for the analysis of data collected during observations and interviews conducted with the chosen grade 8 learners. After the data reduction process, constant comparison analysis was applied in coding and underlying themes identification. The themes in this study outlined how geometric patterns were developed, algebraic reasoning evidence provided and how learners extended and generalised their patterns. Learners were each issued with a box of matchsticks. Due to geographical and socio-economic status that prevailed in that environment, matchsticks became an easily accessible resource that could be used to facilitate the understanding of the concept. Learners were further instructed to construct their geometric patterns, develop numerical relationships or rules from their constructed patterns and extend the patterns for generalisation. Generalisation would determine that the learners are able to separate the critical features of the geometric and numerical patterns so that they can connect working with the two patterns through experiences gained in previous and present interactions. An action learning environment was chosen such that learners could actively show their creativity and take ownership of their activities while gaining algebraic reasoning and a deep mathematics understanding.

The lesson observed resumed when the teacher, that is, the first author, supplied the learners with boxes of matchsticks. The teacher then wrote the instructions that would guide the learners' exercise on the chalkboard. She specified that it was the choice of the learner to choose a particular pattern that he/she wants to design using the matchsticks. A competitive environment was also created as she said, 'Let us see who will create the most attractive geometric pattern and be able to tell us its rule and also be able to extend it.'

RESULTS AND FINDINGS

During observations a video camera was used to capture the learners' activities in action learning environment as they were creating their patterns. The observation schedule was used to capture how learners (i) developed their geometric patterns, (ii) used the tools provided, (iii) displayed their understanding of patterns and relationships. Some of the pre-tasks discussed with the learners prior to the classroom practice observed are displayed in Table 1.

Table 1: Conceptualisation of patterns

Geometric pattern	Conjecture	Rule/general term (T_n)
	3 blocks x term number (n) + 2 blocks $= 3 \times 1 + 2$ $= 5$	3 blocks x term number (n) + 2 blocks $T_n = 3(n) + 2$ $T_1 = 3(1) + 2 = 5$
	3 blocks x term number (n) + 2 blocks $= 3 \times 2 + 2$ $= 8$	$T_2 = 3(2) + 2 = 8$

Although some learners were able to extend the geometric pattern to three or more blocks in the given representation, they experienced challenges in conjecturing and providing the general rule. The advancement of algebraic reasoning was not matching the formulation and diagrammatic representation of geometric patterns.

Observation 1

This is evidently captured in a snapshot as reflected in Figure 1.



Figure 1: Learner 1's attempt

When the learner was requested to describe his constructed pattern, he said.

Learner 1: No, what I figured out here is a small square flat, a gable that would be our kitchen and then a bigger flat for me and my siblings.

Teacher: But you were required to construct a pattern

Learner 1: Oh yes, that is why I have one flat attached to the gable made out of three matchsticks, and the one after made out of 6 sticks. So if I continue, I will build another gable.

Teacher: Alright then let us see how you will write your numerical pattern and rule out of this

Evidently, learner 1 tried to first identify the most important facts surrounding the case given to him. The interviews assisted the teacher to unpack his conceptual understanding of pattern although he figuratively represented his pattern in the form of a home. The responses given by the learner indicated that although he could contrast what a pattern is, he was unable to separate the structural representation created from a growing geometric pattern. Rather his interpretation of the constructed structure was figurative and could not validate conjectures. This made it difficult for the learner to generalise the rule of the pattern. The problem here could lie in the fact that when the numeric and geometric patterns are treated as separate entities, co-variation thinking is not supported. Hence the learner could not verify and make a conjecture that checks the validity of his separated pattern. The separation of the specific or particular features of patterns was not clear initially from the pattern constructed.

Observation 2

Learner 2's work displayed in figure 2 indicates that the learner was aware of the critical features of a geometric pattern and could discern the structures of the object of learning.



Figure 2: Learner 2's work

An interview with learner 2,

Teacher: I see that you have used a different basic shape to construct your pattern. Could you tell us about it?

Learner 2: Yes, I like hexagons, they remind me of the bee hives I usually see next to my uncles' home, they are shaped like this

Teacher: Are you sure it is a bee hive and not a honey comb that is like a hexagon?

Learner 2: Maybe, I'm not sure how you name these things, but I mean that thing that holds honey.

Teacher: Then it is a honey comb. I see that you have also represented your pattern with a drawing. Can you now interpret it numerically such that you form a rule?

Learner 2: That is exactly what I am trying to do now

The learner seemed to have identified the main issue in the pattern, the basic shape and how the pattern grows. Stuurman (2014) suggests that it is important for the pedagogy in patterns to start with understanding the use and definition of rule and term. When learners are required to extend patterns, they are expected to find a general rule. They are therefore expected to break up the rule into its different operations in their correct order. Thus working with geometric patterns reinforces working with numbers, operations and relationships. Thus learner 2 drew up a table to assist him numerically in establishing a general rule for the pattern he created. Since this work was initiated by the learner, it then becomes easier for them to explain and share the information on pattern interpretation and therefore apply algebraic reasoning.

CONCLUSION

It is an idea in this study that the teaching of patterns should start by allowing learners to visualise by learning geometric patterns before they could attempt numeric patterns. Further, emphasis is put on this paper that geometric and numeric patterns should be linked in a single activity, and not treated as separate entities for separate activities. Linking geometric and numeric patterns where the first activity would include working on geometric patterns to create numeric patterns, can lead learners to discover the patterns on their own. It would be easier for learners to realise the origin of the numbers and at the same time be able to generate the pattern. Learners' self-discovery is another way of enabling them to formulate a conjecture about fused geometric and numeric patterns. The process described for discovery learning in learning patterns calls for open systems of teaching and learning in an action learning environment. It is therefore an important task for every teacher of mathematics to help learners to recognise, generalise, and use patterns that exist in numbers, shapes, and in the world around them. Students who have such skills are better problem solvers, have a better sense of the uses of mathematics, and are better prepared to work with algebraic functions. Some observations indicated that in learning patterns learners battle with procedural knowledge in numeric and geometric patterns, instead of considering the relationship between those patterns.

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PEDAGOGY OF PLAY AND METACOGNITION IN INTERMEDIATE PHASE MATHEMATICS

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ABSTRACT: This paper reports on a Master's degree study which still needs to be conducted. In this paper, we explore how reflection on pedagogies of play (PoP) focussing on puppetry as component of teachers' pedagogical content knowledge (PCK), can enhance intermediate phase mathematics teachers' metacognition. We highlight the advantages of the use of puppetry as a PoP in the mathematics classroom. We explore how professional development workshops can scaffold teacher learning across the Zone of Proximal Teacher Development (ZPTD) while fostering their metacognitive awareness. An interpretive-qualitative approach as research design will be employed. Social constructivism will be used as theoretical framework and Third Generation Cultural Historical Activity Theory (CHAT) as research lens. Data collection instruments will include four professional development workshops. Video recordings will be made and group interviews will be constituted before, during and after these workshop sessions.

Keywords: Pedagogy of play; puppetry, pedagogical content knowledge; metacognition; intermediate phase; professional development; Zone of Proximal Teacher Development.

INTRODUCTION

The transmission mode (on which teachers still rely) is out-dated for knowledge needed in the 21st Century. Learning 21st Century skills requires 21st Century teaching (Saavedra & Opfer, 2012). Unfortunately, teachers are under-qualified in their profession to live up to the expectations of 21st Century teaching, therefore professional development of teachers is necessary (Osamwony, 2016).

CONCEPTUAL FRAMEWORK

Various intermediate concepts contribute to exploring how reflection –as an aspect of metacognition - on pedagogies of play (as component of teachers' PCK) can enhance intermediate phase mathematics teachers' metacognition (i.e. metacognitive knowledge, self-regulation, and reflection) before, during and after professional development workshops, forming the theoretical-conceptual foundation of this research. These concepts are four-dimensional education (as component of 21st Century teaching), PCK, PoP (puppetry), metacognition, and teacher professional development.

Four-dimensional education

Teaching in the 21st Century requires teachers to develop learners with navigation skills to find their own way in an uncertain world (Fadel, Bialik & Trilling, 2015). The 21st Century learner do not have to reproduce content knowledge, but rather have to align knowledge gained from innovative teaching-learning situations and apply it in real-life situations (Fadel et al. 2015). Four-dimensional education as suggested by the Organisation for Economic Co-operation and Development (OECD) in 2015, is one way in which teachers can equip learners with navigational skills.. Figure 1 pertains to four-dimensional education.

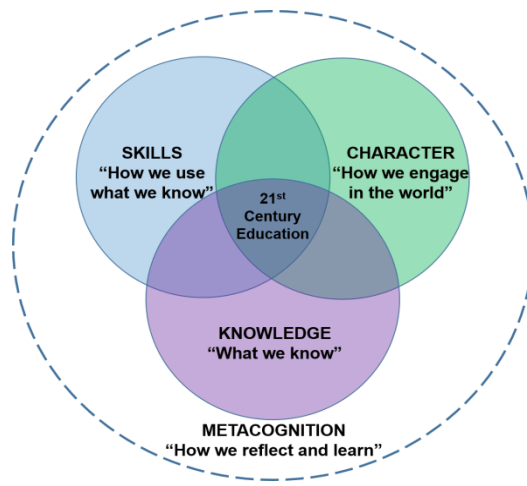


Figure 1: Four dimensional education (adapted from Fadel et al., 2015, p. 43)

Teachers not only have to equip learners with knowledge, skills and character qualities to strive in a 21st Century, but they also need metacognition (or meta-learning). The knowledge domain refers to what learners know and understand about the world around them (indigenous knowledge). The knowledge domain strives to be interdisciplinary (Fadel et al. 2015). The skills domain refers to a hands-on, minds-on approach where learners get to apply what they already know and combine it with creativity, critical thinking, communication and collaboration (Fadel et al. 2015). The character domain refers to certain characteristics necessary when engaging with the world (Fadel et al. 2015). Teachers can develop and foster these characteristics by applying PoP (i.e. puppetry). Pedagogies of play might hold affordances that other pedagogies (i.e. games, drama and music) might not present and may assist teachers in the teaching-learning situation to improve access to concepts, procedures and relationships in abstract school mathematics, making it more meaningful and accessible to learners (Brits, de Beer & Mabotja, 2016; Rusling, 2009). Lastly, metacognition (or meta-learning) refers to how teachers and learners reflect, learn, adapt and transfer knowledge before, during and after teaching-learning situations. Metacognition improves teachers' teaching-learning, because of constant reflection on who, what, when, where and how they teach, growing the mind set of learners to reflect on their learning in the same manner (Fadel et al. 2015).

In order for teachers' metacognition (thinking about their thinking) and their general teaching-learning praxis to improve (referring to the four-dimensional education model), this research study aims to introduce teachers through professional development workshops (PD workshops) to both puppetry as a pedagogy of play and metacognition (metacognitive awareness). Professional development workshops should be organized in ways that closely align teachers' professional practice, including opportunities to enact certain (innovative) teaching strategies and materials, with reflect before, in and on their practice (Van Driel & Berry, 2012).

Pedagogical content knowledge

Initially introduced in the 1980's by Shulman, PCK can be defined as the knowledge teachers possess relating to specific strategies and approaches necessary to make content meaningful and accessible for particular learners (in a specific context/situation). Pedagogical content knowledge enables the identification of prior knowledge learners possess, how it links to new knowledge, and provides knowledge of learners' misconceptions (Shulman, 1987; Van de Walle, Karp & Bay-Williams, 2013; Gravett & de Beer, 2015). In this research, it should be established that PCK will serve as a construct where the focus will be on PoP - puppetry - as a component of PCK.

Pedagogy of play

Pedagogy of play refers to pedagogical models that support the development of play from the perspective of learners (Fleer & Veresov, 2018). Play discourses are usually child/learner initiated, adult guided or policy-driven relating to educational play and refer to dance, drama, music and puppetry (Wood, 2014). Pedagogies of play require a playful classroom environment where learners take risks, make mistakes and explore new ideas (Mardell, Wilson, Ryan, Ertel, Krechevsky & Baker, 2016). In this research, teacher participants will be introduced to puppetry as a pedagogy of play.

Puppetry

Puppetry has not been widely researched in mathematics in South Africa particularly, and even less in the intermediate phase classroom (Quintero, 2011). Pedagogies, such as puppetry are an innovative way to engage learners in the teaching-learning process (Dahlstrom, 2014). Puppetry is one of the most ancient forms of entertainment which is believed to have originated since 3000 years BC (Brits, et al. 2016). Teachers are hesitant to use puppetry as pedagogy (Brits, et al. 2016). Puppetry has a pedagogical advantage: teachers who use puppetry creates the opportunity for alignment between learners' real-life experiences and the problem of the puppet character (Keogh, Naylor, Maloney & Simon, 2008). Puppetry creates possibilities for creativeness, collaboration and critical thinking while enhancing social skills, language development and self-confidence (Soord, 2008; De Beer, Petersen & Brits, 2018).

Metacognition

John Flavell coined metacognition as this term as "thinking about thinking" (Flavell, 1979, p. 906). Metacognition is a complex concept defined differently by various authors (Scott & Levy, 2013). Metacognition nurtures independent thinkers and lifelong learners who are able to grapple with new situations and learn how to learn (teach) and continue learning (how to teach) throughout their lifespan (El-Koumy 2004). Incorporating metacognition in professional development of teachers has the potential to enable them to regulate, and thereby self-direct - his/her own teaching and learning (Mahdavi 2014).

According to Flavell (1976: 232), the nature of metacognition has two main dimensions namely (i) metacognitive knowledge and (ii) self-regulation. These dimensions have several components which are underlying defining its character (Roebers, 2017). Metacognitive knowledge concerns person (teacher him-herself /learners), task (teaching or learning) and strategy variables (Garcia, Rodriguez, Gonzalez-Castro; Alvarez-Garcia & Gonzalez, 2016). According to Crescenzi (2016), knowledge about learners (also teachers as learners) refer to the knowledge teachers possess regarding their own and learners' cognitive capabilities, self-efficacy, motivation and interest. Knowledge about the task refers to the knowledge teachers possess regarding learners' knowledge of the task context (demands) and the possible difficulties and misunderstandings they might have when engaged with the task (Crescenzi, 2016).

Self-regulation consists of planning, monitoring and evaluation of your own or others practice (Basso & Abrahão, 2018). Teachers engaging in planning, set specific goals which learners have to meet to complete the lesson or task successfully (Zumbrunn, Tadlock & Roberts, 2011). However, they have to choose what pedagogy are available and will contribute to learners' performance or understanding. Teachers engaging in monitoring, monitor the effectiveness of the teaching-learning strategies they themselves as well as their learners employ during the lesson or task (Zumbrunn, et al. 2011). Teachers evaluate whether the goals of the task (lesson) have been successfully met by learners – evaluation allows for overall lesson or task improvement (PCK) by the teacher to limit or prevent difficulties and misunderstandings (Zumbrunn, et al. 2011). Gravett and De Beer (2015) view self-regulation as reflection for, in and on teaching-learning actions, while Cornoldi (2009) views the tendency to think about a task (teaching a specific topic to a specific grade) – producing a metacognitive conceptualisation of the task – and to use metacognitive knowledge and self-regulation - as reflection (Cornoldi 2009; 2012).

In South Africa, there are relatively little research done in the South African context regarding metacognition and its role in the pedagogies implemented in mathematics teaching-learning (Van der Walt, Maree & Ellis, 2006). Therefore, a need exists for scholarly research in this arena.

Teacher professional development

Teachers are characterised by transmission-mode teaching-learning practices and in order to change this, teacher professional development is necessary (De Beer & Kriek, 2018). Professional development workshops aimed at improved teaching-learning practices, should (i) identify problems central to

teaching-learning practice and (ii) devise a pedagogy assisting teachers to infuse these new ideas into their classrooms (Kennedy, 2014). It is essential that teachers are afforded with the opportunity to experiment, practice and reflect on these teaching-learning experiences based on the tools professional development workshops provide them with (Girvan, Conneely & Tangney, 2016). Professional development workshops will be constituted, allowing the researchers to explore how participating intermediate phase mathematics teachers' metacognition (metacognitive awareness) can be scaffolded across the ZPTD while implementing pedagogies of play (puppetry) (Warford, 2011). The ZPTD consists of four stages which will be discussed in table 1. By scaffolding teachers' learning, the researchers aim to address their metacognitive awareness by providing them with the opportunity to implement what they have learned during the professional development workshops in their classrooms. Metacognitive awareness urges growth of teachers and the increasing trajectory instilled within the design principles of professional development workshops, supports this notion (De Beer & Mentz, 2017). Table 1 illustrates how professional development will be used in this research and how it is interrelated to the ZPTD (Warford, 2011); metacognitive skills and strategies and the overall theoretical-conceptual framework of this study.

Table 1. Professional development in this research

	Professional development workshop session 1: (Introductory and orientation workshop)	Professional development workshop session 2: (Lesson planning workshop)	Professional development workshop session 3: (Reflection, evaluation and refinement workshop)
Link with ZPTD	(i) Self-assistance stage: Establishing current knowledge teachers possess by sharing classroom experiences related to teaching-learning experiences (Warford, 2011; De Beer & Mentz, 2018; Cornoldi 2009; 2012)	(ii) Expert other stage: Analysis of teaching practices (i.e. infusing pedagogies of play [puppetry] into existing lesson plans). Introducing the concept metacognition and its role in teaching-learning environments (Cornoldi 2009; 2012) The researchers act as facilitators and the participating teachers as mentors to each other (iii) Internalisation stage (automatisation): Participating teachers engage in teaching-learning utilising pedagogies of play (puppetry). Hence, these teachers "practice" the new skills / strategies which they have gained from the professional development workshops (Warford, 2011; De Beer & Mentz, 2018) Opportunities are provided for participants have to reflect on their new practice (Cornoldi 2012)	(iv) Recursion stage: (de-automatisation) Reflection before, during, after, and overall experiences of presented lesson(s) and professional development workshops (Warford, 2011; De Beer & Mentz, 2018)
Link with SDL	(i) Teachers taking initiative in diagnosing their learning needs by setting learning/professional development goals for themselves as the professional development workshops commence (Knowles, 1975; De Beer & Kriek; 2018; Cornoldi 2009; 2012) Prompts that will require teachers to be metacognitively aware of their own thinking, will be provided continuously	(ii) Participating teachers identify human and material resources in compiling a lesson plan while utilising pedagogies of play (puppetry) in order to achieve the identified learning goals (Knowles, 1975; De Beer & Kriek; 2018). Metacognitive prompts will be provided as initial guidelines for teachers' thinking and decision making (Van der Walt 2014) (iii) Teachers transfer pedagogies of play (puppetry) as an appropriate learning strategy based on their knowledge gained in the professional development workshops thus far. Metacognition supports transfer of newly learned skills and knowledge to new situations (Cornoldi 2009)	(iv) Teachers evaluate learning outcomes of the presented lesson based on their new knowledge. In the same sense, they link this new knowledge with prior knowledge regarding teaching-learning experiences to adapt their teaching learning strategies for utilisation when faced with a similar situation. Metacognition are known to be conducive to knowledge and skill transfer
Link with conceptual framework	(v) Four-dimensional education as suggested by Fadel et al. (2015) and (vi) metacognition as suggested by Flavell (1979) is especially fostered here (v) Four dimensional 21st Century education is fostered here due to participating intermediate phase mathematics teachers being introduced to puppetry as a pedagogy of play, fostering a "hands on-minds on" approach in the mathematics classroom (Fadel et al. 2015) (vi) Metacognition is fostered here concerning all of the variables involved in the metacognitive knowledge, self-regulation and reflection dimensions when participating intermediate phase mathematics teachers plan their lessons while infusing puppetry and presenting the lesson on their own time between workshop session two and three (Flavell, 1979; Crescenzi, 2016; Cornoldi 2009; 2012)		

Self-directed learning

According to Knowles (1975, p.18) self-directed learning (SDL) can be defined as "a process in which individuals take the initiative, with or without the help of others in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes". According to Van Der Walt (2014) and Havenga (2017), SDL is an individual, motivated undertaking where teachers

manage all aspects involved in teaching-learning such as setting goals for the lesson, making informed decisions to scaffold the lesson with appropriate skills and strategies in order for learners to obtain the learning goal. These much needed skills are only a few, characterising SDL and teachers should be given the opportunity to transfer these characteristics as obtained from professional development workshops, making it explicit in their teaching-learning practice and to reflect thereupon to constantly improve it (Nepal & Steward, 2010; Van Der Walt, 2014).

THEORETICAL FRAMEWORK

The researchers propose to use Third Generation Cultural Historical Activity Theory (CHAT) as overarching lens as conceptualised by Engeström (1987) which stems from social constructivism. Figure 2 pertains to third generation CHAT theory and illustrates how it will be applied in this research.

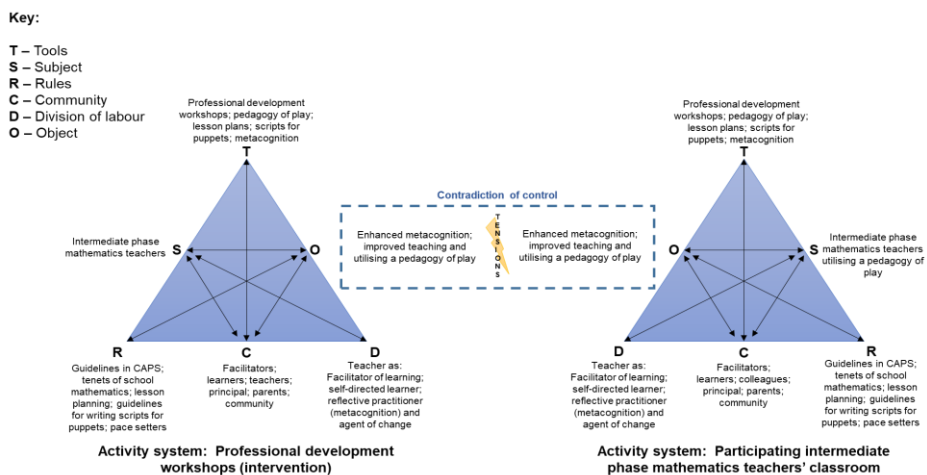


Figure 2: The CHAT lens that will be used in this research

Third Generation CHAT theory has underlying concepts pertaining to its construct. The individual (teacher) is the subject who uses tools to obtain a common teaching-learning goal (object) in an activity system. The activity system refers to a certain setting with definite rules and role players in the community surrounding this system, each with their own role referring to the division of labour (Mentz & De Beer, 2017). Two activity systems will be used in this research namely (a) the professional development workshops (intervention) and (b) the participating intermediate phase mathematics teachers' classrooms.

According to Engeström (2009), a researcher should always use two interdependent activity systems as a minimal unit of analysis. The researchers intend to compare the two activity systems as illustrated in figure 3, in order to attain focus on the objects of them. In two activity systems a contradiction of control exists (McNeil, 2013; Mentz & De Beer, 2017). By comparing the two objects of each of these activity systems are tensions can be expected (Mentz & De Beer, 2017).

RESEARCH METHODOLOGY

The research pertaining to this study is qualitative in nature. Three professional development workshops will be constituted. Semi-structured open-ended individual interviews will be constituted with the participating intermediate phase mathematics teachers before and after each of the professional development workshops. Workshop one will inform participating intermediate phase mathematics teachers with regards to the different pedagogies (i.e. dance, drama and music), introduce them to puppetry as well as metacognition (pertaining to metacognitive awareness). During workshop two, the participants will choose to plan lessons while infusing puppetry. Participants will also be assisted in writing puppetry scripts and prompts be provided to actively involve them in their thinking individually and collectively- for use in workshop three. The researchers will observe participants (and make field notes) during their engagement in the planning of the lesson. After the participants finalised their lesson, one participant will have the opportunity to present this lesson to

their intermediate phase mathematics class. The researchers will record this lesson on video. During workshop three, participants will have the opportunity to reflect, evaluate and refine the presented lesson. The researchers will observe participants (and make field notes) during their engagement in the reflection on the presented lesson. A video recording will also be made of this reflection workshop to strengthen the researchers' field notes gathered during the observations of this workshop session. The professional development workshops will be presented on three consecutive Saturdays.

Population and sampling

Three schools in the JB Marks municipal district will be approached and intermediate phase mathematics teachers will be invited to voluntarily participate in the professional development workshops on the three consecutive Saturdays. It is estimated that N=9.

Data collection instrument

Two semi-structured individual interviews (before and after) the professional development workshops will be constituted. The first interview will establish what participants' views are of pedagogies of play (puppetry) and metacognition (reflection for, in and on teaching-learning situations). The second interview will establish what participants' views are of pedagogies of play (puppetry) and metacognition (reflection for, in and on teaching-learning situations) after it has been introduced to them and they have engaged in puppetry script writing. Determining teachers' views of mathematics, the adapted Views of mathematics questionnaire developed by Seldon and Seldon (1996) will be used. Determining teachers' metacognition (metacognitive awareness), the adapted Metacognitive Awareness Inventory for Teachers questionnaire developed by Balcikanli (2011) will be used. It is important to note that these questionnaires will be used to inform and assist the researchers in the development of an interview schedule used to interview each participant. Each of the interviews will be recorded on an audio recorder.

Data analysis

Due to the qualitative nature of this research, the researchers proposes to use content analysis as proposed by Creswell (2014) and values coding as proposed by Saldaña (2015) in each of these phases to analyse the data that emerges from these interviews, observations and video-recordings. Participants' reflection based on pedagogies of play (puppetry) and their metacognitive experiences with such a pedagogical method will be considered as codes in this study. The codes will be categorised in order for emerging themes to arise (Saldaña, 2015).

Trustworthiness of data

The trustworthiness of this investigation will be strengthened as a variety of data sources will be collected over four to six weeks. Participants will get the opportunity to verify the data and the interpretation thereof. No generalisations will be made (Creswell, 2014; Maree, 2016).

FINDINGS

The findings will enhance our understanding of how reflection on pedagogies of play (puppetry) as component of teachers' PCK can enhance intermediate phase mathematics teachers' metacognition after professional development workshops have been implemented.

CONCLUSION AND RECOMMENDATIONS

The integration of puppetry in the intermediate phase mathematics classroom is an inexpensive aid for teaching and learning and may assist in the transfer of knowledge. Transfer is the ultimate goal of education, as students are expected to internalize what they learn in school and apply it to life. The dilemma for teachers is that educational success is no longer mainly about reproducing content knowledge, but about extrapolating from what we know and applying that knowledge in novel situations. These changes require different pedagogies in teaching mathematics (Fadel et al. 2015).

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LEARNERS' CONDITIONS THAT FACILITATE EFFECTIVE MATHEMATICS TEACHING: A CASE OF TWO SECONDARY SCHOOLS IN MAHIKENG

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ABSTRACT: The study reported in this article sought to investigate learners' conditions that facilitate effective mathematics teaching in the two selected Mahikeng secondary schools. The authors used a sequential explanatory design following a mixed-methods design where qualitative data informed quantitative data. For the purposes of this article, only quantitative data is presented. A structured questionnaire was used in the quantitative phase in which 360 survey instruments were issued to mathematics learners and 321 responses were returned. SPSS 23 was used to analyse quantitative responses. Descriptive statistics such as the mean, standard deviation, variance and frequency distributions were used to describe study respondents. These statistics were also used to describe and identify learner conditions that facilitate effective mathematics teaching in the selected secondary schools. The Pearson coefficient revealed a mixture of negative and positive insignificant relationships among constructs identified i.e. learner conditions. It is evident that there are high correlations (in excess of 0.3) looking at the correlation matrix. The performance of one attribute in one way or the other has a certain influence on the other element. The p-value of most of the elements is less than 0.01 and 0.05 levels of significance, confirming the interrelations between the elements.

Keywords: effective teaching, effective mathematics teaching, effective learning, content knowledge

INTRODUCTION

Science and mathematics education, as well as skill development seem to have grown to be the key components that influence the development of any country. Education and skills are primary elements for stimulating and increasing these countries' socio-economic competitiveness. The study by Chetty, Friedman and Rockoff (2014) has established that teachers have an influence on their learners' school and life-long accomplishments. Learners need effective mathematics teachers to enhance them to compete outstandingly in the present technological world. Effective teaching is one of the effective factors influencing learner attainments in mathematics (Pretorius, 2013). Teachers have to play a great role as they have a significant impact on what their learners do, and assist learners overcome challenges in performing well in mathematics (Rice, 2003).

PURPOSE OF THE STUDY

The purpose of the study reported in this article was to pursue the following research question:

What are the learner conditions that facilitate effective mathematics teaching?

In responding to the main research, the following secondary research questions were used:

- What are the possible learner elements that affect effective mathematics teaching in the selected secondary schools?
- Are there any correlations between the possible learner elements that facilitate effective mathematics teaching?

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Coe, Aloisi, Higgins and Major (2014) described effective teaching as teaching that leads to improved student outcomes which have an impact on their future success. Seah (2007) argued that effective teaching and learning can be a case of collaborations amongst teachers and their learners, amongst learners and between the class and its setting. As a result, effective teaching is reflected by effective learning. Effective mathematics teachers are mostly goal-driven through various approaches like

learner-discovery as well as teacher-directed approaches in carrying out mathematics teachings, thereby making some mathematics teachers more effective than others (Seah, 2007).

Effective learning can possibly be associated with various learner factors. Learner factors denote what the learners convey to the class. It embraces the nature of the societal upbringing of the learners - their attitude, goals, interest and proficiency level, motivation, their prior knowledge, beliefs and dispositions they carry into class with them. These can inspire learners' classroom relations and consequently impact on the teachers' effectiveness. Teaching involves the procedure of learners' scores in a standardised test to quantify the effect of teachers' teaching on the students. For some time, learners' academic performance in both external and internal examinations had been utilised to assess teachers' effectiveness.

Learners' examination scores are habitually used as a measure of educational output for the reason that learners' test scores have been revealed to be certainly associated with their secondary school pass rate, future job prospects, as well as adult earnings (Currie, 2001). Teachers have a major influence on learners' academic success for it is teachers that are in due course answerable for rendering educational policy, as well as curriculum intents into learning prospects for the learners. Learners' average scores can well reflect the outcome of a teacher's effective teaching. As a result, an accepted measure of teacher effectiveness might artificially be the typical attainment test scores of his/her learners. Their blend of investigation pointed out that learners' test scores can be used as a benchmark for teacher effectiveness.

RESEARCH METHODOLOGY

Research design

The authors in this article used one of the basic mixed methods design namely, the explanatory sequential design (Creswell, 2015). A mixed-methods design has the capacity of generating sufficient, intricate and astute knowledge. The authors considered the quantitative wing of the study in this reported article.

Sampling

There are around 84 secondary schools in NMM district and only two schools were chosen as case studies. The two selected schools include a highly effective school and a less effective school on the basis of grade 12 results. Within the selected secondary schools, the study participants were 200 mathematics learners in grade 11 and 12 per selected school. Grade 11 mathematics learners were selected as participants as they are in the Further Education Training (FET) pre-exit level with the belief that they are in a position to clarify some matters concerning mathematics learners in their respective schools. In total 360 grades 11 and 12 mathematics learners participated in the study reported here.

Data collection instruments

A questionnaire was used to collect data for this article. In general, effective mathematics teaching was the dependent variables. The dependent variables were continuous data as theoretically they have an infinite number of values in a continuum. The determinants were the independent variables.

The validity and reliability of questionnaire

Leedy and Ormrod (2010) suggest that *face validity* is the measure to which the researcher assumes the mechanism monitors what it is conceived to follow. The units of the questionnaire were formulated in such a way that they test the aspects that they are planned to measure. De Vos (2006) asserts that for the questionnaire to have content validity, a literature review overlaying the majority of the theory about the research question has to be carried out, hence the representativeness was displayed. The authors used a pilot study to check the validity and reliability. To confirm that units in the questionnaire are reliable, the Cronbach Alphas were computed on the questionnaire that used the Likert scale. Subsequently, reliability established the determinants of effective mathematics teaching in NMM district secondary schools. The study adopted a commonly accepted rule to describe internal consistency as suggested by Cronbach and Shavelson (2004). It that indicates that if $0.7 \leq \alpha < 0.8$ then

internal consistency is acceptable. Due to the sample used in this study, a benchmark of 0.7 was referred to as a measure of internal consistency of the instrument used. The calculated Cronbach's alpha from the 41 items of 321 responses was 0.869 which is almost 0.9.

Data analysis

Ary, Jacobs, and Razavieh, (2006) assert that data analysis take in attempts to follow the phenomenon under study, produces information and illuminates relationships, speculates about how, as well as why, the relationships look like they do, and connect up the new knowledge with what is by now known. Descriptive statistics, as well as inferential statistics are usually applied to analyse the quantitative data. Pearson's correlation coefficients were used to establish whether there is a relationship between the learner conditions and effective mathematics teaching in NMM district secondary schools.

Ethical considerations

Denzin and Lincoln (2005) point out that social research should be ethical in that it respects the dignity and rights of the respondents avoids harm to the participants, and runs with honesty as well as integrity. The authors provided all the details about the purpose, procedures and benefits of the research to the participants prior to starting with the research. The authors got permission from the NMM education district office to officially involve mathematics learners from the selected schools.

RESULTS AND DESCRIPTIVE ANALYSIS

Learner conditions factor refers to what the learners bring to the class. It embraces the nature of the social upbringing of the learners - their attitude, motivation, concerns and skill level, their past knowledge, aims, beliefs and characters they convey into class with them. These can impact learners' classroom collaboration and thus influence the teachers' teaching effectiveness. The authors sought to seek the responses of learners on the factors/conditions that facilitate effective mathematics teaching. Empirical results on the analysis of learners' responses are discussed in this section. The learner data was primarily gathered to provide data to create indicators of effective mathematics teaching. The study was concerned with comprehending learner elements or determinants concerning mathematics to the extent that these informed the study about the learners' classroom mathematics teacher, hence effective mathematics teaching. The following results as depicted in Table 1 is used to describe the KMO test.

Table 1: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.830
Bartlett's Test of Sphericity	Approx. Chi-Square	3970.142
	Df	820
	Sig.	0.000
	Determinant of matrix	2.270E-6

According to the results presented, the sample used is meritorious as it ranges between 0.80 and 0.89 and the sphericity test is rejected, implying that the sample used is adequate and the matrix is not singular. The fact that the determinant of a correlation matrix is not equal to zero also confirms the non-singularity of the factors. Factor analysis was found to be suitable as the test revealed a value of 0.000. Therefore, different factors are expected from the data. The instrument used to collect data is good according to Cronbach and Shavelson (2004:395). This is confirmed by 0.869 reliability statistics results of the suggested exploratory factor analysis of 41 items for this study.

Presented in this section are the Factor Rotated results. Factor rotation simplifies the factor structure, yet still allows the factors to be inter-related. The authors was however cautious when interpreting the factors. Correlation coefficients suggested by Norusis (1994:205) were adopted when interpreting the factors. In Table 2 below, empirical results of the article are presented to answer the first secondary

question. According to Mavetera, Moroke and Sebetlele (2015), quantitative studies use data of good quality and the data presented should be in an acceptable form. Learners were asked to rate the extent to which they agreed or disagreed with those elements they identify with. The perception of learners about the elements impacting on effective mathematics teaching is positive, as presented in the Table 2 below.

Table 2: Learner conditions elements

	Variances
Self-perception on mathematics	7.689
Attitudes concerning mathematics	2.945
Self-assessment	2.345
Independent learning	2.171
Affinity to teachers	1.835
Learning repertoire	1.308
Orientation to learning	1.200
Learner-teacher support material	1.170
Adjustment to school	1.143
Parental support	1.074

According to the results presented in Table 2, the general impression gathered is that respondents concur around the ten conditions suggested by the authors. The correlation coefficients of the rotated factors are generally significant as a confirmation that learners either agreed or strongly agreed about these factors. There were few respondents who were of a different view and that led to a lack of or poor convergence in some of the factors such as independent learning where learners disagreed on their participation in mathematics group-work and undertaking of independent mathematics research activities (Mercer, 2006, p. 507).

Some learners also had different opinions as far as learning repertoire is concerned. According to them, there is nothing interesting about mathematics lessons as their teachers fail to use innovative ways of teaching (Okoye, 2002, p. 562) which end up with dyscalculia (Vaidya, 2008, p. 717). Among other things, learners complained about support structures and lack of resources due to vandalism and theft. Makgato and Mji (2006, p. 254) found that mathematics remains abstract without LTSM. The variances for each of the ten factors were calculated to confirm their divergence. The factors were found to be different as expected but also less correlated after factor rotation was imposed. It is also evident that most of the learners' responses coincided more on their self-perception on mathematics, affinity to teachers, and orientation to learning and parental support.

According to learners, the 10 elements highlighted are of importance to their learning mathematics. Their responses confirm that "Self-perception on mathematics" is one factor that schools should pay special attention to. The variance of this factor is greater than that of others. The three second most important factors highlighted by learners are "attitudes toward mathematics", "Self-assessment" and "Independent learning" with variances 2.945, 2.345 and 2.171 respectively. Other factors are important even though they received lower ratings in terms of the variances than others. This is a confirmation that the 10 attributes could be used as learner conditions to improve learner performance in mathematics in the selected schools.

In Table 3, empirical results of the article are presented to answer the second secondary question.

Table 3: Correlation matrix

		A	B	C	D	E	F	G	H	I	J
A	γ	1	-1.00	0.887	1.000	-2.41	-1.00	0.054	1.000	0.670	-0.78
B	γ	-1.00	1	-1.00	-1.00	-1.00	1.00	-1.00	-1.00	-1.00	1.00
C	γ	0.887	-1.00	1	1.000	-0.32	-1.00	0.921	1.000	0.957	-0.53
D	γ	1.000	-1.00	1.000	1	1.000	-1.00				
E	γ	-0.24	-1.00	-0.32	1.000	1	-1.00				
F	γ	-1.00	1.00	-1.00	-1.00	-1.00	1				
G	γ	0.054	-1.00	0.921	1.000	0.308	-1.00	1			
H	γ	1.000	-1.00	1.000	1.000	1.000	1.000	1.000	1	1.000	-1.00
I	γ	0.670	-1.00	0.957	1.000	0.265	-1.00	0.746	1.000	1	-0.69
J	γ	-0.78	1.00	-0.53	-1.00	-0.39	1.000	-0.095	-1.00	-0.697	1

Keys: γ - Pearson Correlation; A-self-perception; B-attitudes concerning mathematics; C-self-assessment; D-independent learning; E-affinity; F-learning repertoire; G-orientation to learning; H-learner-teacher support material; I-adjustment to school; J-parental support.

It should be noted that blank spaces on the table of factors are for statements which learners had disagreements on. There is an observable entry of 1(one) in each row which is to the right in the row immediately above it. These suggest the matrix with infinitely many solutions hence the system is dependent. These indicate that the elements are inter-related as it comes from the population of inter-related correlation matrix. These conclude that there are multiple correlations between the learner elements that facilitate effective mathematics teaching.

CONCLUSION

The results of the study within its framework successfully responded to the basic unit of investigation. As a matter of evidence, it validates that the 10 elements could be used as learner conditions to improve learner performance in mathematics in the selected schools. From the above research findings, it is irrefutable that the learner conditions differ from school to school and need constant evaluation in order to achieve the objective of effective mathematics teaching. Lastly, there is evidence of a mixture of negative and positive significant and insignificant relationships between the ten elements. It is evident that there are high correlations (in excess of 0.3) looking at the correlation matrix. It is also evident that the correlation matrix is not unitary, providing a strong relevance between the ten learner elements. This further endorses the viability of the multiple relationships between these learner elements which affect effective mathematics teaching.

The research reported in this paper can definitely play a role in effective mathematics teaching and learning particularly in the developing countries. The findings reported contribute more knowledge (in South Africa) to literature on learner conditions that facilitate effective mathematics teaching. It therefore, poses a question to mathematics teachers not only to stimulate learners' curiosity in mathematics and to teach mathematics effectively, but also to interrogate learner cohort conditions each year.

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Competing interests

The authors affirm that they have no financial or personal relationship that may have inappropriately influenced them in writing this article.

Authors' contributions

Author 1 was instrumental in collecting and capturing data from mathematics learners in the two selected schools. Author 2 assisted in member-checks, peer debriefing and ethical matters. Author 1

was the project leader and played an important role overseeing the analysis and its interpretation. The two authors continued to work on the finalization of the paper.

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FUNCTION FOLLOWS FORM: UNDERSTANDING THE ELEMENTS OF ADOLESCENT MATHEMATICAL WRITING

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ABSTRACT: Mathematics is a written language, and this language is composed of three elements: symbols, nominalizations, and images (Seo, 2015). However, when people think about math, often ideas about equations and images come to mind, only two of the three elements. The aim of this study is to understand the kinds of writing grade 7 and 8 students are producing in their math classes. In this study, mathematical writing samples for in-class assignments were collected from 125 grade 7 students and 130 grade 8 students over a six month period. Using methods of discourse analysis, writing samples were coded across each grade and with individual students over time. The focus of the analysis was on the three elements. Preliminary analysis showed that students wrote according to the form of the assignment that was presented to them. Whether it was grade 7 students or grade 8 students, both groups conformed to the tasks that the teacher presented to them.

Key words: Mathematical writing; adolescents; writing elements

AIM OF THE RESEARCH

In 2000, the National Council of Teachers of Mathematics (NCTM) in the United States wrote mathematical principles and standards that students should know at each grade level. These standards focus on not only mathematical knowledge but also how that knowledge is conveyed in written and oral forms. Their goal is to improve mathematical knowledge and application for all students. It has been 18 years since those standards were developed. If looking at PISA and TIMSS scores, NCTM didn't achieve its goal.

Mathematical instruction needs to change. However, before any changes can happen, it's necessary to understand what students are writing in their mathematics class. As a result, the focus of this study is to get an understanding of what and how students are currently writing mathematically.

RESEARCH QUESTION

For this study, the research question is: What kinds of mathematical writing are students in grades 7 and 8 producing during their routine instruction? It is necessary to understand what and how students are writing mathematically before any changes in pedagogy can be designed and implemented.

THEORETICAL FRAMEWORK

All writing is comprised of elements, and those elements are part of its discourse (Gee, 2014). Mathematical writing is no different. Mathematical writing is comprised of three basic elements: symbols, nominalizations, and images (Seo, 2015).

Symbols are any mark on a surface that convey meaning, and that meaning changes according to context (Harris, 1995; Rotman, 2000). For example, “—” is just a horizontal line. However, when it is typed as “mixed-methods,” it is a hyphen. While in this context, “5-2,” it denotes subtraction. Keep in mind that it is the same horizontal line, only its context changed. Symbols are the essence of

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mathematics. They are objects that convey meaning, and this meaning is contingent on the social context and accepted discourse. Its combination provides the mathematical language used in its understanding (Sfard, 2000). As a means of condensing the mathematical meaning into its smallest component, symbols delegate complex cognitive tasks to an external environment (Van Dyck & Heefer, 2014). Math can be seen as a transposition of symbols. Even though the format of the equations change, as each process is carried out, it is essentially the same as the previous equation. The equations may look differently, but the meanings are similar. The way students use symbols is a product of their environment. Teachers model the "correct" way to use the symbols, and the students will emulate it in order to get a positive grade from the teacher.

Nominalizations are highly condensed acronyms, words, and phrases to explain a more complex idea. It is a type of thematic condensation (Lemke, 1995). These meaning-packed words are nominalizations. The term "nominalization" is when an activity including its participants and circumstances is put into a noun form. Once in this form, the noun is used instead of describing the whole activity and/or explaining the complete process. It is seen as the shortest or easiest way to describe an action or concept. For each genre, the specific knowledge, processes and context need to be specified, in order for the nominalization to be understood (Van Dijk, 2008). Thematic condensation works because there is a tacit agreement on the meanings of the words. This nominalization process is an example of thematic condensation, where the implied activity can be qualified and related to other activities in a condensed manner. Mathematics by its nature is condensed, and the economical use of symbols shows the greatest amount of meaning in as few "words" as possible (O'Halloran, 2008). In geometry, CPCTC is an acronym that students need to learn; it means congruent parts of congruent triangles are congruent. Prior to understanding the acronym, students need to first understand the concept of congruency and how this concept is applied to triangles.

Images are anything that is not a symbol or a nominalization (O'Halloran, 2008). They can range from diagrams, organizational tools (i.e. T-chart for geometric proofs), to tables and graphs. Similar to nominalizations, images can be highly condensed, using one image to convey multiple concepts. These elements can represent mathematical ideas in succinct ways. For example, a line graph can have more than one meaning, such as changes over time or the relationship between two variables. As previously stated, mathematics, by its nature, is a form of writing that is compact and impactful. Images are one kind of compaction.

One of the difficulties of learning math is the negotiation of these three elements. Mathematical discourse and condensation promotes a kind of elitism (Lemke, 1995). For example, when stating "SSS Inequality," mathematicians can identify the postulate. It represents only one postulate, no others. Nominalizations and other condensed vocabulary have determined meanings, and those meanings are agreed upon within the member of "the club." Any opposition to these meanings is not tolerated. Similar to other non-native languages, mathematical and scientific language tends to be exclusive. Those people who are not able to negotiate these three elements fluently will not be able to communicate to others in this field.

METHODOLOGY

Prior to any data being collected, approval was granted from Chicago State University's Institutional Review Board and the Superintendent of this school district. PJH is a junior high school in a suburb of Chicago. The first meeting was with the math department. This department has 10 teachers, and all 10 teachers signed assent forms to be part of this study.

During school year 2017-2018, this school had 653 students in grades 7 and 8 (Illinois State Board of Education, 2018). Of the 696 students, 654 students submitted both the student assent form and the parent consent form (94% return). Of these 654 students, 125 grade 7 students and 130 grade 8 students agreed to be part of this study (39% return). Teachers were asked to submit copies of their students' work every month from November 2017 to April 2018. It was each individual teacher's

decision on what work to submit. As a result, 1,276 pieces of writing were collected. Due to student absences, not all students submitted all six samples. The goal was to obtain a variety of writing samples, from only the use of symbols to the use of symbols, nominalizations, and images.

These writing samples were analyzed through discourse analysis. Discourse analysis focuses on not only what is written but also in what context, where it was written (Gee, 2014). For all of these writing samples, the context is the same: the math classroom. Therefore, the focus was on what the students wrote, not where. These writing samples were coded according to the three elements of mathematical writing: symbols, nominalizations, and images. Preliminary coding focused on the writing samples of each grade level. The focus of these themes was to identify similarities and differences among the grade 7 students as a whole and the grade 8 students as a whole.

RESULTS

In the preliminary analysis, the student writing samples were examined as two units. One unit is the grade 7 students, and the second unit is the grade 8 students. It was necessary to examine the kinds of writing as a whole before examining it into parts.

For both grades, students wrote according to what was expected of them. These expectations can be expressed as oral directions and/or presentation of mathematical concepts and problems. Since there were no observations of teachers’ interactions with their students, the focus of this study is on the written presentation of the mathematical problems. These presentations can be in the form of a problem on the chalkboard (i.e. Solve for x: $2x+3=9$), an assignment in a math textbook (i.e. On page 24, complete problems 1, 3, and 5), or they can be part of a worksheet. When students complete problems from the chalkboard and the textbooks, they do not write the question first and then solve the problem. Instead, students solve the problem on loose-leaf paper and give it to the teacher to grade (See Figure 1)

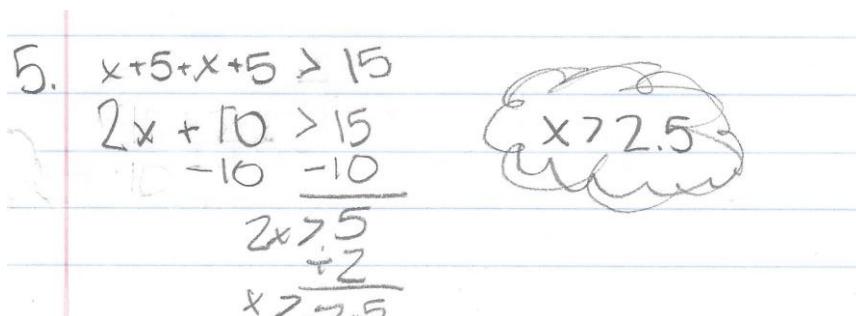


Figure 1: Grade 7 student’s work on loose-leaf paper

Grade 7 Students

Students in grade 7 who presented mathematical calculations on loose-leaf paper either used only symbols, used symbols and nominalizations, or used symbols and images. None of the grade 7 samples contained symbols, nominalizations, and images simultaneously. For example, in Figure 2, this student used symbols and nominalizations. The symbols are the numerals and mathematical notation, and the nominalization is “slope.”

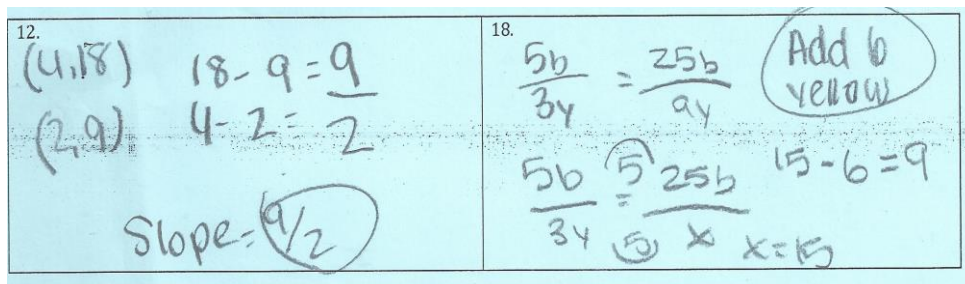


Figure 2: Grade 7 student's use of symbols and nominalization

An example of a grade 7 student using symbols and images can be seen in Figure 3. In this example, the student used numerals, mathematical notation, and a triangle. From the way it is written, it seems that the triangle was drawn to help the student understand the problem.

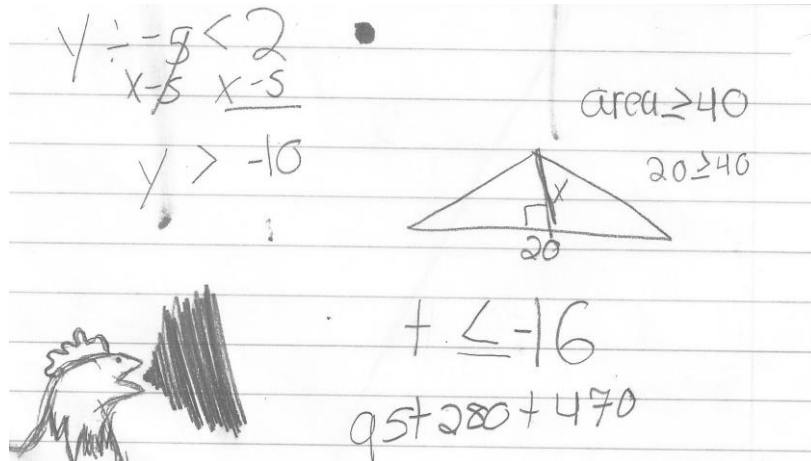


Figure 3: Grade 7 student using symbols and images

When grade 7 students were given a worksheet, they conformed their writing to the expectations of the worksheet. There is no extraneous information, and all of the answers are within the confines of each box (see Figure 4).

Question	YES Write the answer as a fraction. In simplest form.	NO Write the answer as a decimal. In simplest form.
1. Do you have a sibling?	$\frac{87}{100}$.87	$\frac{13}{100}$.13
2. Did you ride the bus to school today?	$\frac{46}{100}$.46	$\frac{54}{100}$.54
3. Do you own a pet?	$\frac{71}{100}$ %	$\frac{29}{100}$ %
4. Do you play on a sports team at Park?	$\frac{34}{100} = \frac{17}{50}$	$\frac{66}{100} = \frac{33}{50}$
5. Are you wearing the color blue today?	$\frac{70}{100}$ % .7	$\frac{30}{100}$ % .3
6. Is your birthday in December?	$\frac{11}{100}$ %	$\frac{89}{100}$ %

Figure 4: Grade 7 student conforming to the worksheet

Grade 8 Students

The grade 8 teachers preferred to use worksheets out of a workbook that corresponded with their textbook. Similar to the grade 7 students, grade 8 students wrote within the confines of the worksheet. However, unlike the grade 7 students, grade 8 students used symbols, nominalizations, and images simultaneously, when the worksheet asked for that kind of writing. As seen in Figure 5, student 255 used the appropriate kinds of element when asked.

Nr: 255 Date: _____ Period: _____

Exit Ticket 2 = 255 2 hr = 120 min

1. The table shows the number y of calories you burn in x hours of jogging.

A. Write a linear function that relates y to x . F&D

Equation: $y = 400x$

Hours Jogging, x	Calories Burned, y
2	800
4	1600
6	2400
8	3200

B. Interpret the slope and the y -intercept in the context of this problem.

The slope is 400 because for every hour you run you burn 400 calories and the y -intercept is 0 because if you start off by not running you not burning calories

C. Graph the linear function. Be sure to label and scale your graph.

D. How many calories do you burn in 150 minutes? 830 calories

2 hr = 120 min
 $+ 10 = 130$
 $+ 10 = 140$
 $+ 10 = 150$

800
+ 30
830

Figure 5: Grade 8 student example using symbols, nominalizations, and images

DISCUSSION

Surprisingly, no new information was learned. In 2009, Seo found that students conform their writing according to their audience. In that study, grade 10 students solved and explained a mathematical problem in English class and/or math class, and results showed that students conformed their writing according to their audience. The students in the English class wrote words to the English teacher; students used only symbols and images to their math teachers, and students who wrote in both English and math classes changed their writing (Seo, 2009). In this study, students also conformed their writing according to their teachers. However, in this case, they conformed their writing according to the form that was presented to them. This characteristic is clearly seen in Figures 2, 4, and 5. In Figures 2 and 4, students wrote all of their answers within the boxes that were given to them. These students did not have stray writing outside of the boxes. The student used symbols (equations), nominalizations (words) or images (graph) only in the sections that asked for it.

Students used the mathematical elements that were asked of them. In the grade 7 examples, students wrote what was necessary to answer the question (Figures 1, 3). However, because there was not proscribed format, the students wrote in the manner that was helpful to them. For Figures 2 and 4, the students wrote what was asked of them on the worksheet, staying within the confines of the directions. This conformity exists amongst all of the writing samples across grade 7 and grade 8, which shows that the students are aware of their audience, the teacher, and what is expected from them.

CONCLUSION

As stated earlier, this analysis is preliminary. It was an opportunity to get a general idea of the kinds of writing students produced. Both groups of students used symbols, nominalizations, and images when asked by the teacher. They conformed their writing to the expectations of their teachers. Additional analysis is necessary in order to understand if this conformity is only seen at the surface level or if it exists at the linguistic level as well. In the U.S., there has been an emphasis on independent thinking in mathematics classes. This study showed that the students are still conforming to expectations.

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PRIMARY SCHOOL PRESERVICE TEACHERS' VIEWS OF MATHEMATICIANS

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ABSTRACT: The purpose of this paper is to (1) design and pilot test an instrument to measure preservice teachers' ($n=36$) views on what mathematicians do, and (2) use a tool to measure their conceptions of mathematicians. This should illuminate the importance of doing "mathematics" in primary schools so as to enculturate our learners into the mathematical habits of the mind and rebuild the tattered image of our beloved discipline. In framing this study, I drew on Toulmin argument pattern (TAP). Central to this design is the notion of mathematical proof for the reason that proof is the touchstone of mathematicians' practices. Analyses of the questionnaire data showed that the instrument is reliable and a valid diagnostic tool to gain insights into preservice teachers' views of mathematicians and can be used to design subsequent interventions. In addition, the results showed that preservice teachers hold naïve views of mathematicians. Recommendation emanating from this study is that the school mathematics curriculum requires revision to incorporate proof across all grades in an effort to turn the tide against the distorted image the discipline has attracted from the general public and thus let learners experience the "real deal".

Keywords: Mathematicians practice; proof; proof validation; argument

INTRODUCTION

Very little is known about primary school preservice teachers' views mathematicians. Yet much of the mathematics they learn and prepare to teach in their future career has its genesis in mathematicians. In this study, "mathematician" refers to theoretical or research mathematicians. This focus on research mathematicians is consistent with Valdes' (2012, p. 128) definition of a mathematician as 'a person who not only studies mathematics but also does research in mathematics'.

Gaining insights into preservice teachers' views is important because these views tend to influence learners' perceptions of the nature of the discipline. According to Dossey (1992), teachers communicate subtle messages to learners about the nature of mathematics that "affect the way they grow to view mathematics and its role in their world" (p. 42). Thus, naïve views not only contribute to the prevalent negative image which the general public attaches to mathematics but also further reduces the already declining learner participation in high secondary school mathematics.

LITERATURE REVIEW

A handful of studies have examined learners' views of mathematicians work. Picker and Berry's (2000) explored the views of primary school learners and found evidence suggesting that the primary inhibitor of learners' opportunity to gain informed conceptions of proof stems from the perpetuation of societal stereotypes about the mathematics discipline and mathematicians. Tall, Yevdokimov, Koichu, Whiteley, Kondratieva, and Cheng (2012) define mathematical proof as "a sequence of assertions, the last of which is the theorem that is proved and each of which is either an axiom or the result of applying a rule of inference to previous formulas in the sequence" (p. 15). In this study, the term "mathematical proof" is used to define a mathematician's activity in which a finite sequence of logically connected statements (e.g., definitions or axioms) to establish the truth of a proposition. However, "proof" is used in its broadest sense to refer to an argument that one makes to justify a claim and to convince oneself and others of the claim's veracity; thus, this definition encompasses empirical or rigorous arguments.

The primary activity of mathematicians is to formulate conjectures and seek proofs thereof. The notion that proof distinguishes mathematical practices from scientific behaviour in other disciplines is not

contested. Mathematicians advance mathematical knowledge by developing new principles and recognising previously unknown relationships between existing principles of mathematics. Although these mathematicians seek to increase basic knowledge without necessarily considering its practical use, such pure and abstract knowledge has been instrumental in producing or furthering many scientific and engineering achievements. Therefore, to think of mathematicians as people who enjoy the challenge of a problem is not entirely incorrect; however, it is a naïve view in the context of school geometry.

Burton (1999) interviewed 70 research mathematicians to investigate how they understand their practices, the results point to the false social stereotype, promoted and reinforced by the media, of the male mathematician, locked away in an attic room, scribbling on a whiteboard and, possibly, solving Fermat's Last Theorem. According to Picker and Berry (2000), the perception that mathematicians engage in mathematics applications similar to those seen in mathematics classrooms was prevalent, including solving simple arithmetic problems. The individualistic and competitive climate in which mathematicians work notwithstanding, they embrace the notion of a community of practices on the grounds that corroboration increases the quantity and quality of ideas and enables the exploration of areas that could not be explored had they been working in alone (Burton, 1999). The term "problem" here is used to denote any open mathematical question whose solution is not readily available.

PURPOSE OF THE STUDY

As far as I could ascertain, *Google* and *Google Scholar* searches with key search terms such as "measuring mathematicians work" or "scales for measuring mathematicians' practices" yielded no appropriate results. It was precisely this gap that my study attempts to fill. The review of the literature indicates that very little is known about the nature of preservice primary school teachers' conceptions of mathematicians. The purpose of this study is to fill the void and thus extend existing research on these teachers' views on knowledge construction. To this end, a quantitative study designed to capture preservice teachers' views was designed and operationalised to seek answers to the following research question: How are mathematics preservice teachers' views of the practices of mathematicians?

THEORETICAL FRAMEWORK

In thinking about what mathematicians do, I framed the study based on what I believe is the primary work with which mathematicians pride themselves: creating proofs and validating them. It is for this reason that Toulmin's (Toulmin, 2003) argument pattern (TAP) was a useful framework for this study. Given Selden and Selden's (1995) concept of "validation of proof" is readings of, and reflections on, proofs to determine their correctness. TAP is a model that describes six constitutive elements of argumentation and the relationships between them: claim, data, warrant, backing, rebuttals, and qualifiers. The elements are categorised into two triads. The first triad, deemed the core necessary to make an argument, comprises claims, data, and warrants. Due to space constraints, I only define the three elements of the core triad. In this study, the term "argument" is taken as referring to an attempt to convince an interlocutor of the truthfulness of their claim or conclusion. In support of the claim, the arguer draws from the data (evidence or given statements). A warrant is a proposition that explains by connecting data to claim. However, the interlocutor can reject the warrant on the basis that the claim is flawed as it does not match the data.

METHODOLOGY

Setting

The research setting was an undergraduate mathematics education module offered in the second semester for prospective primary school teachers at a large public university in KwaZulu-Natal, one of the nine provinces in South Africa. For Intermediate and Senior Phase preservice teachers, the enrolment of mathematics module that incorporate informal proof is mandatory. These modules integrate both mathematical content and mathematical knowledge for teaching (MKT). According to Hill, Blunk, Charalambous, Lewis, Phelps, Sleep, and Ball (2008, p. 431), MKT refers not only to the mathematical knowledge common to individuals working in diverse professions, but also the subject

matter knowledge that supports that teaching (e.g., why and how specific mathematical procedures work, how best to define a mathematical term for a particular grade level, and the types of errors learners are likely to make with particular content).

Participants

The preservice teachers ($n=36$) who volunteered to participate in this study were recruited from a large public universities in the South African province of KwaZulu-Natal. Demographically, participants were primarily black and female (87%) with an average age of 22. Informed consent was sought and confidentiality and anonymity guaranteed. Preservice teachers were an interesting group to choose because I believe that the learning and teaching of mathematics will improved only when these teachers demonstrate informed understandings of what it means to engage in mathematical activities (conjecturing and proving to be precise) like mathematicians and demonstrate these understandings in their instructional practices. A recent simulations study by Wolf, Harrington, Clark, and Miller (2013) found that sample size requirements ranging from 30 (simple CFA with four items and factor loadings of .80) were sufficient for piloting testing an instrument. More specifically, sample sizes varying from 15 to 30 respondents were enough for a pilot study (Maholta, 2009).

Instrumentation

I designed a 12-item Likert scale and requested five preservice teachers to face validate it. Two adjustments were made to terminology (conjecturing was changed to guessing, and proposition to statement). Further, a fellow doctoral student in the university where the author is based was requested to evaluate the content of the scale. Feedback was incorporated into the final scale. The result was a one-page, two-sided questionnaire (Appendix A). This questionnaire was administered to the participants in their lecture hall during which time the purpose and instructions were read and participants' questions clarified. This survey questionnaire comprised two segments: short demographic questions and a 12-item Likert scale consisting of two dimensions: Mathematicians Practice and Proof Validation.

All the 12 items in the scale were derived from literature on mathematics as practiced by contemporary mathematicians. However, attitudes have direction and intensity. Hence, the items were compartmentalised into two components: positively (+) marked items represented informed views deemed consistent with the mathematical practice while negatively (–) represented naïve views deemed as misconceptions and distortions in the mathematical enterprise and reverse scored. In addition, “Strongly Disagree” is coded as 1 and “Strongly Agree” is coded as 5. In this scale, a high score reflects informed views while a low score denotes naïve views on the practices of mathematicians. In addition, negatively marked items were included to eliminate error responses.

RESULTS AND DISCUSSION

Sample characteristics

The data were treated as continuous given Likert's (1932) original argument that survey respondents actually construe the response scale in terms of evenly-spaced points along an underlying attitude continuum. The interval data generated from Likert scale items were subjected to SPSS Version 16 for analysis. In order to ensure that inferences drawn from the data were valid, it was important to assess whether the sample was drawn from a normally distributed population. A Shapiro-Wilk test (Table 1) confirms that the data were approximately normally distributed since $p > .05$ (Wilson & MacLean, 2011) with no outliers.

Table 2: Distribution of data scores

Tests of Normality						
	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Mathematicians_Scale	.116	36	.200*	.977	36	.637

Scale validity and reliability

The need to pilot and establish validity and reliability of the scale used in this study arose because of two reasons. One is that there is a need to establish the quality of inferences drawn from this study. Two is that this is a "new" scale because, as already mentioned, I am not aware of any other scale purporting to measure preservice teachers' views of mathematicians practice. The term "validity", used here generally in its broadest sense, means the degree to which evidence and theory support the adequacy and appropriateness of interpretations and inferences based on data (Messick, 1992). The term "reliability" refers to a measure of the internal consistency of the scale. The scale's reliability was investigated through determining internal consistency. The overall Cronbach's alpha of the scale was .446. Given that there is no sacred acceptable or unacceptable level of alpha, a level as low as .50 may still be useful if the questionnaire is of adequate length (in terms of items not cases) and its construct validity is established (Schmitt, 1996).

A multiple linear regression analysis was used to investigate both construct and criterion validity by assessing how well the Likert scale items of the three factors (mathematicians' practice; knowledge construction; and, proof validation) predict preservice teachers' views on mathematicians' practice (Total Score). The correlation coefficient matrix provided the answer (Table 3). Correlations of .80 or higher between subscales (functions of proof) were indicative of multicollinearity (Wilson & MacLean, 2011). For this scale, all the correlations between the scales were significant in that they were above the threshold of .30 (Tabachnick & Fidell, 2013) and below the limit of .80 and therefore indicating that there likely was not a problem using any of two subscales correlated.

Table 3: The correlation matrix for determining validity

Inter-Item Correlation Matrix			
	Mathematicians'_Practices	Proof_Validation	Score_Total
Mathematicians'_Practices	1.000		
Proof_Validation	.413	1.000	
Score_Total	.695	.650	1.000

In order to determine the size of the subscale that predicted preservice teachers' scores on mathematicians' practices, the Model Summary was used. In Table 3, the sizes of the prediction variables are laid out. The results suggest that the subscales are statistically significant predictors of preservice teachers' ability to gain informed conceptions of mathematicians ($p < .000$). The overall correlation of the two subscales with preservice teachers' scores is an adjusted R squared of .36. Therefore, only 36% of the overall variation in preservice teachers' conceptions of mathematicians is explained by these two subscales. Given that this is an educational research, the R-squared value of 36% signifies that the results have practical significance; identifying factors that predict informed views of the mathematical enterprise is valuable in a country whose learners experience difficulties in mathematics.

Table 4: The variability in preservice teachers; views explained by the three subscales

Model	R Square	Adjusted Square	R Std. Error of the Estimate	Change Statistics				
				Change	F Change	df1	df2	Sig. F Change
1	.374	.362	4.43080	.374	32.596	3	164	.000

Likert scale

A five-tiered grading scale was used to score preservice teachers' views on mathematicians. Mean responses were interpreted according to the categories of views in Table 4.

Table 4: The normative map based on preservice teachers' (n = 36) mean scores

Classification	General explanation	Mean score range		Count	f (%)	c f
		From	To			
Unencultured	Naïve	0	<1.5	3	1.8	3
Poorly encultured	Naïve	1.5	<2.5	22	13.1	25
Moderately encultured	Hybrid	2.5	<3.5	6	3.6	31
Highly encultured	Informed	3.5	<4.5	4	2.4	35
Extremely encultured	Informed	4.5	<=5	1	0.6	36

A closer analysis of the data suggested that these few views were those related to what preservice teachers themselves have experienced in school. Specifically, the vast majority (84%) of preservice teachers tended to believe that a mathematician works on topics similar to those they were exposed to in their own mathematics classes. Put another way, I found that most preservice teachers think that the mathematics done in their past and present classes does not differ much from that done by mathematicians. This findings seem to underscore the scarcity of proof – the heartbeat of mathematics – in classrooms. These preservice teachers seem to hold views that tend to be similar to learners' views. For instance, Picker and Berry's (2000) developed a tool with which to investigate and compare secondary school learners' images of mathematicians in five different countries. They found that most learners across all the countries held stereotypical images of mathematicians. Generally, Misfeldt and Johansen (2015) conducted interviews with 13 mathematicians to obtain the best possible understanding of their work. They found that despite discussions in educational research and policy on engaging learners in formulating mathematical problems 'we do not yet have an adequate understanding of how mathematicians (and other relevant societal groups) handle this part of their working process' (p. 358). This finding can be attributed to the gulf between school mathematics and the research mathematician's work is wholly different areas of study (Valdes, 2012). The concern here is that given these naïve views, further distortion is certain. Hence it is not unreasonable to call for teacher education programmes that capacitate teachers with informed views of the nature of mathematics embedded in the proof concept.

CONCLUSION

The results provide evidence that vast majority of preservice teachers who participated in this study hold naïve views of mathematicians. The implication of these results is that as teacher educators and researchers, we need to revise the curriculum in ways that preservice teachers experience proof in most of their topics in the mathematics modules. There are three limitations: small sample size, close-ended items, and the work-in-progress nature of the scale. For instance, further insights could emerge about the practical significance of the subscales on preservice teachers' views of mathematicians. In addition, although the results suggest that this scale can be used to assess preservice teachers' conceptions of mathematicians, confidence in it will grow as it is used with larger populations. Given

that the scale is two-dimensional, I see this effort as work requiring further development. Also, better insights may be gained if preservice teachers' responses were probed so as to enable them to explain their choices in the questionnaire.

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APPENDIX A: WHAT MATHEMATICIANS DO

Mathematicians' Practices		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
MP1	Mathematicians aspire to be the first to publish in their particular areas of interest. (+)	1	2	3	4	5
MP2	Mathematicians engage in mathematics topics similar to those I have seen in my own mathematics classes. (-)	1	2	3	4	5
MP3	Mathematicians work collaboratively in their research work. (+)	1	2	3	4	5
MP4	A mathematician works on simple arithmetic calculations (-)	1	2	3	4	5
MP5	Mathematicians want to know if the guesses they make about mathematical objects are true and why. (+)	1	2	3	4	5
MP6	The environment in which mathematicians work is not competitive. (-)	1	2	3	4	5

Proof Validation		Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
PV1	It is important to ensure that each statement in the proof is true. (+)	1	2	3	4	5
PV2	A proof is correct if two parallel columns of "statements" and "reasons" are divided by a vertical line. (-)	1	2	3	4	5
PV3	Each statement in a proof must be checked whether it logically follows from the preceding statements or from other accepted statements. (+)	1	2	3	4	5
PV4	A proof is judged as valid by virtue of its author or source. (-)	1	2	3	4	5
PV5	Proofs are accepted or rejected on the bases of their own merits. (+)	1	2	3	4	5
PV6	There is no need to check the correctness of proofs because mathematicians have proved them as correct. (-)	1	2	3	4	5

OPINIONS ABOUT MATHEMATICS ANXIETY: HOW TO REDUCE IT

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ABSTRACT: Mathematics anxiety could affect the development of pre-service mathematics teachers to teach mathematics effectively and eventually influence mathematics performance of learners. The paper addresses opinions of pre-service teachers' about mathematics anxiety and the reducing of it. The study adopted an exploratory qualitative research approach using an open-ended questionnaire. The sample consisted of 133 fourth-year FET and senior phase pre-service mathematics teachers from a university in South Africa. The results indicate that mathematics anxiety could be reduced by 1) sufficient preparation, practice and intervention programs; 2) utilising cultural artifacts, such as indigenous games, clothing and artworks, and 3) using cooperative teaching strategies. The paper contributes by foregrounding suggestions to reduce mathematics anxiety and add to research in the field of ethno-mathematics.

Keywords: Mathematics; anxiety; pre-service mathematics teachers; performance.

INTRODUCTION

Mathematics is an essential part of all communities' daily lives (Selin, 2000). In particular, mathematics occurs in simple applications, such as determining differences in prices of items in shops, drawing household budgets and balancing of statements. However, many regard mathematics as one of the most difficult subjects at school level and could only be executed by highly intelligent learners. Other reasons learners experience mathematics as challenging could include poor teaching methods and the abstract nature of mathematics, which could eventually lead to mathematics anxiety.

Mathematics anxiety is a feeling of stress that could affect the development of a mathematics pre-service teacher to teach mathematics effectively and eventually influence mathematics performance of learners. Research (Ashcraft & Moore, 2009; Devine, Fawcett, Szücs & Dowker, 2012; Hemree, 1990; Scarpello, 2007) indicates that mathematics anxiety is a meaningful obstacle for mathematics performance

The paper addresses pre-service teachers' opinions about mathematics anxiety and the reducing of it. The research questions are thus: 1) What are pre-service mathematics teachers' opinions about mathematics anxiety? and 2) How can mathematics anxiety be reduced?

LITERATURE OVERVIEW

A possible reaction towards learners with mathematics anxiety is to make ignorant comments such as 'You must just handle it' or 'get over it' or 'so what?' Such reactions, according to Ashcraft and Moore (2009), do not address the relation between mathematics anxiety and aspects, such as personal, educational and cognitive functioning. Therefore, this discussion on mathematics anxiety will start by defining the concept. Then, causes of mathematics anxiety, followed by consequences of mathematics anxiety and how it manifest will be provided. Lastly, suggestions to reduce mathematics anxiety by focusing on previous research studies will be provided.

Various researchers (Ashcraft & Moore, 2009; Hemree, 1990; Jain & Dowson, 2009; Morris, 1981; Wong, 2005) over the past years provided definitions for the concept *mathematics anxiety*. Mathematics anxiety is a fear for any contact with mathematics, including communication with the mathematics teacher, written work and assessments (Wong, 2005). Jain and Dowson (2009) claim

mathematics anxiety is a feeling of tension clashing with number manipulation and solving of problems. Ashcraft and Moore (2009) define mathematics anxiety as learners' negative emotional reactions on situations, which include numbers and mathematics calculations. Mathematics anxiety reactions may vary from minimal to serious, from a small frustration to a meltdown emotional eruption, for example learners start crying if they have to write a mathematics test. According to Hemree (1990) mathematics anxiety is an unpleasant emotion, which is out of proportion and a threat affecting a learner's future. Morris (1981) adds that mathematics anxiety is a condition of panic, tension, helplessness and fear.

From the previously mentioned definitions, it is clear that some people experience an inability to manage when confronting with any mathematical situation. Mathematics anxiety is a feeling of stress that could affect the general wellness of a mathematics teacher to teach the subject effectively or a learner to execute mathematics satisfactory and may eventually influence mathematics performance of learners. Thus, it is important to view some causes leading to mathematics anxiety.

Learners experience mathematics anxiety for various reasons, such as fear to forget, worrying to obtain poor results, afraid of their inability to solve a mathematics problem, distress that the mathematics problem is too difficult to do or to execute the mathematics principles correctly. Another concern includes limited time to complete mathematics assessments. According to Scarpello (2007) mathematics anxiety could also be a result of previous experiences in the mathematics classroom, parents' influences and remembering of previous poor achievements in the subject.

Mathematics anxiety has certain consequences divulging in different forms, which may affect learners suffering from it. Mathematics anxiety manifest in various ways, such as memory lost during mathematics examinations, panic or total avoidance to execute mathematics related tasks. Thus, mathematics anxiety reduces mathematics achievement regardless a person's level of mathematics competence (Ashcraft & Moore, 2009). Many learners fear and become anxious when doing mathematics. Avoidance to do mathematics can be observed in terms of learners' involvement and participation in mathematics lessons, time spent to study mathematics and regular submission of homework. Hemree (1990) confirms that mathematics anxiety not only relates with poor performance in mathematics assessment, but also with participation in the subject, which indirectly influences attitudes towards mathematics and avoidance of it.

Ashcraft and Moore (2009) claim that people with mathematics anxiety avoid courses, which include mathematics, or mathematics-related careers. Many learners therefore limit their career option by avoiding studies in mathematics. Several countries can also not address their shortages in the area of mathematics, sciences and technology effectively.

After considering the causes and consequences of mathematics anxiety, it is crucial to focus on ways of remediating mathematics anxiety by focusing on previous studies on mathematics anxiety. Hemree (1990) notes some treatments to reduce mathematics anxiety, such as cognitive restructuring in combination with relaxation exercises, such as mathematics games, outside the classroom and group counseling. Dorothea (2018) also found that psychodrama treatment brought forth significant changes in some learners' levels of mathematics anxiety. Nevertheless, Scarpello (2007) argues that teachers are playing a key role in reducing mathematics anxiety by utilising effective teaching methods. In particular, Kalaycioğlu (2015) revealed by enhancing teachers' levels of self-efficacy, mathematics anxiety could be reduced. Dove and Dove (2015) found students exposed to flipped classroom approaches had significantly decreased anxiety scores. Gresham (2007) also established a statistically significant reduction in mathematics anxiety of 248 pre-service teachers by using manipulative and concrete learning of mathematics content. Finlayson (2018) found in a study with 70 pre-service teachers in Canada that forcing participants to face their mathematics anxiety empowered them to device strategies, which enabled them to overcome mathematics anxiety.

RESEARCH METHODOLOGY

The study adopted an exploratory qualitative research approach using a survey. The survey was an open-ended questionnaire consisting of two questions, namely 1) How do you experience mathematics anxiety currently? and 2) How can mathematics anxiety be reduced? The sample consisted of 133 pre-service mathematics teachers purposively selected. All participants were fourth-year FET and senior phase mathematics pre-service teachers studying full-time at a particular university in South Africa. They agreed to participate voluntarily in the study. Data were analysed inductively using thematic content analysis.

DATA ANALYSIS

The solutions to the questions were read thoroughly to get a holistic view, where after redundant information were removed. The data were analysed by using open-coding (Saldaña, 2009). Common codes were categorised and themes were identified. Table 1 indicates the themes identified.

Table 1. Themes, categories and sub-categories transpired from the data analysis

Theme	Category	Sub-category	N
Current experiences of mathematics anxiety	Reasons for experiencing mathematics anxiety	Unpreparedness	11
		Reduced work tempo	1
		The nature of mathematics (problem solving and difficult concepts)	37
		Large quantity of mathematics content and limited time	14
		Lack of self-confidence	4
		Attention distraction	1
		Group work	1
		Unrealistic expectancies	2
		Motivation	2
		Reasons for not experiencing mathematics anxiety	Practice and revision
	Teaching strategies focusing on discovery		1
	Nature of mathematics (practical)		12
	Resources		2
	Strategies to reduce mathematics anxiety	Meaningful mathematics	Preparedness, practice and intervention
Teachers			12
Group work			4
Basic principles of mathematics			13
Self-directed learning			1
Motivation			6
Time			9
Reduced work load			2
Resources			1
Psychological preparation			11

RESULTS AND DISCUSSION

From the 133 participants, 105 responded to the question on their current experiences of mathematics anxiety (78.9%), which indicate that mathematics anxiety affects most pre-service mathematics teachers and is a construct to consider. In particular, the data indicate that the majority who responded to the question (73 of 105 (69.5%)) experience mathematics anxiety, while only (32 of 105 (30.5%)) indicated that they do not experience any mathematics anxiety.

The participants indicating that they experience mathematics anxiety provided various reasons for their condition. Thirty-seven of 73 participants (50.7%), who had noted they suffer from mathematics anxiety, indicated aspects of the nature of mathematics, namely difficult mathematics concepts and problem solving, contributing to mathematics anxiety. Participant 1 acknowledged, "I experience only mathematics anxiety with concepts I have found difficultly to accomplish before the examination, only if I have not practiced enough". Participant 3 complained, "the work is too deep and gives me anxiety attacks". Participant 4 declared, "I struggle with specific complex geometry problems", and participant 5 claims, "I am afraid to solve problems ... the origin of formula". Ashcraft and Moore (2009) agree that mathematics could become abstract and difficult when it includes multiple calculation steps, thinking processes, formula and equations, which, in turn, places a heavy load on the working memory, which could lead to mathematics anxiety.

Fourteen of 73 participants (19.2%), who had acknowledged they have mathematics anxiety, attributed the large quantity of mathematics content to be done in a limited time, while 11 of 73 (15.1%) participants argued teacher unpreparedness, as reasons for mathematics anxiety. Participant 2 noted, "If I am not fully prepared, I experience mathematics anxiety and am very slow in the examination venue". The minority provided other reasons for mathematics anxiety, such as reduced work tempo, lack of self-confidence, attention distraction, group work, unrealistic expectancies and motivation. Scarpello (2007) agrees mathematics anxiety may be the cause of previous unsuccessful experiences in the classroom, lack of motivation and support to learners to take mathematics and learners' inability to remember mathematics achievements.

The participants claiming not to experience mathematics anxiety provided various reasons for feeling stress-free. Twelve of the 32 participants (37.5%), who had indicated that they do not suffer from mathematics anxiety, forwarded the authentic nature of mathematics. Participant 6 noted "it is a practical subject related to real-life activities". Participant 7 claimed mathematics to be "a game full of enjoyment". Participant 8 added, "I can apply it in various contexts". Other motivations uttered by participants claiming that they do not have mathematics anxiety, include personal attributes, such as attitude, passion and self-confidence (9 of 32 (28.1%)), revision and practice (8 of 32 (25%)), appropriate resources (2 of 32 (6.2%)) and teaching methods focusing on discovery (1 out of 32 (3.1%)).

Most participants (127 of 133 (95.5%)) reacted on the question to reduce mathematics anxiety. Almost a third (44 of 127 (34.6%)) of the participants suggested preparation, practice and intervention programs, such as tutorials and extra classes, to reduce mathematics anxiety. Another suggestion forwarded is that teachers should present mathematics more meaningful (24 of 127 (18.9%)). Participant 9 proposed teachers "must be more practical by providing learners with work related to their real life styles". Participant 10 advised mathematics teachers should "use real world objects when teaching a specific topic". Other recommendations made include: a focus on basic principles of mathematics (13 of 127 (10.2%)); qualified teachers to teach the subject (12 of 127 (9.4%)); psychological readiness (11 of 127 (8.7%)); motivation (6 of 127 (4.7%)); more time to complete assessments (9 of 127 (7.0%)); group work (4 of 127 (3.1%)); a reduced workload (2 of 127 (1.6%)); self-directed learning (1 of 127 (1.0%)); and appropriate resources (1 of 127 (1.0%)).

Noteworthy is that 41 of 127 (32.3%) participants who responded on the reducing of mathematics anxiety, gave some indication that ethno-mathematics could enhance meaningful mathematics. Participant 11 commented, "Ethno-mathematics allows learners to see how mathematics relates to their cultural artifacts, which could reduce mathematics anxiety, because it is relevant to their lives". Participant 12 added "ethno-mathematics will bring the outside world to the classroom" and participant 13 noted, "Learners will understand that mathematics is a human activity and will take ownership of it". Other opinions about the value of ethno-mathematics included that ethno-mathematics aligns with learners background, provides meaning to mathematics concepts and makes them less complex, promotes inclusivity, motivates learners to do mathematics, develops critical thinking, builds a love for mathematics, keeps learners at ease and fosters self-confidence, and reduces

stereotyping. Wong (2005) agrees that cultural artifacts using a concrete and cultural context of mathematics motivate learners to study mathematics.

CONCLUSION

Although practical applications of mathematics are evident in all communities and are essential for daily living, mathematics is still viewed by many people as one of the most difficult subjects at school level. Some reasons for experiencing mathematics as challenging could include poor teaching methods and the abstract nature of mathematics, which may lead to mathematics anxiety. Mathematics anxiety is regarded as a meaningful obstacle for mathematics achievement.

The paper addressed pre-service teachers' opinions about mathematics anxiety and the reducing of it. Sufficient preparation, practice and intervention programs, such as tutorials and extra classes, were foregrounded as the most dominant way to reduce mathematics anxiety, followed by presenting mathematics more meaningful by introducing ethno-mathematics. Other suggestions included an emphasis on basic mathematics concepts, competent teachers, psychological preparedness and encouragement, sufficient time for assessments and a lessened workload, group work and self-directed learning and suitable resources.

Apart from the usual intervention classes, tutoring and revision programmes to reduce mathematics anxiety, the researcher suggests, following from the findings, firstly a focus on the nature of mathematics. In particular, the teaching of problem solving by asking stimulating questions could stimulate learners' curiosity to solve mathematics questions, and eventually reduce mathematics anxiety. Through solving of problems, learners get the opportunity to discover mathematics creatively and to think independently (Wong, 2005). Teachers should use their skills to develop high-order questions and have a positive attitude regarding an inquiry-based approach instead of only transferring knowledge.

Secondly, teachers should introduce learners in a particular context before formulating mathematics concepts. This context could be modelled by using cultural artifacts, such as indigenous games, clothing and artworks, which relate to learners' daily lives. The use of cultural artefacts provides learners with the opportunity to engage in problem scenarios which are contextually meaningful and which are aligned with their personal experiences. Mathematics becomes more authentic, because cultural artifacts focus on human contexts. Cultural artifacts assist learners to view mathematics as practical, rather than something to memorise, thus a conversion from knowledge to applications in diverse contexts. The creation of such enjoyable contexts ensure a relaxed climate to reduce mathematics anxiety. Abramovich (2000) adds that pleasant learning experiences change learners' deeply rooted negative attitudes pertaining to mathematics and transform them into enthusiasm to study mathematics.

Thirdly, a cooperative teaching strategy could encourage learners to work together, but also promote respect for each other, which could reduce mathematics anxiety. Zakaria and Iksak (2007) identify five benefits of cooperative learning, namely: 1) positive interdependence; 2) enhanced interaction; 3) individual accountability; 4) interpersonal and small-group skills; and 5) group processing. Group work can develop learners' self-confidence to solve mathematics problems, which, in turn, could reduce mathematics anxiety.

A limitation of the paper is that the empirical inquiry excluded opinions of practicing teachers and learners and focuses only on pre-service mathematics teachers in one specific university context. Further research on strategies using cultural-embedded strategies to reduce mathematics anxiety in diverse contexts is recommended. Another suggestion is to provide guidelines on how teacher-educators can address pre-service teachers' mathematics anxiety so that confident mathematics teachers can enter the profession.

The paper contributes by providing insights into pre-service teachers' opinions about mathematics anxiety and foregrounding some suggestions to reduce mathematics anxiety. In particular, the role of cultural artifacts in reducing mathematics anxiety is highlighted, which add to research in the field of ethno-mathematics. If teachers address learners' cultural values in the mathematics classroom by means of the creation of cultural contexts, learners may experience mathematics more meaningful and enjoyable, which, in turn, could reduce mathematics anxiety. From the 133 participants, 105 responded to the question on their current experiences of mathematics anxiety (78.9%), which indicate that mathematics anxiety affects most pre-service teachers.

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CONSTRUCTING MATHEMATICS AND SCIENCE INSTRUCTIONAL LEADERSHIP PRACTICES FOR HIGH-STAKES TESTING

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ABSTRACT: Mathematics and science learner attainments often negatively tilt high schools' performances in high-stakes testing environments. It is common for school improvement plans to be focused on mathematics and science as high risk subjects. This article compared school leadership practices for improving mathematics and science learner attainments in a performing school in Gauteng province and a non-performing school from the Free State province in South Africa. School leadership functions were used as an analytical framework to examine the schools' organisational processes. Data were drawn from narratives telling the schools' stories for the improvement of mathematics and science as mediated by instructional leadership practices. A combination of directed content analysis and constant comparison techniques were used to construct useful instructional leadership practices in high-stakes testing environments. Good school performances were sustained by a focused vision to involve most learners in mathematics and science education. Purposeful channelling of resources and human capital resulted in relentless efforts to drive instruction. The integration of capacity building through data-driven decision-making and school-based teacher professional development made the vision achievable. The high-stakes testing environment and active parental involvement were used as accountability instruments. Recommendations were made to provide equitable access to instructional leadership tools for all schools.

Keywords: Constructions of instructional leadership; instructional leadership practices; high-stakes testing environments; mathematics and science

INTRODUCTION

High-stakes mathematics and science learner achievements tend to be disappointing for many South African schools. While they tend to pose the greatest threat to high-stakes testing, school improvement plans contain very little to assist learner achievement. Hence, this study explored some of the constructions of instructional leadership practices that sustain learner achievement in high school mathematics and science. The exploration was achieved by comparing a high-performing school and a low-performing school in order to establish some of the instructional leadership practices that sustain learner achievement in high-stakes testing environments. For this study the term high school mathematics and science refers to Grades 10-12 mathematics, physical sciences and life sciences. Under-achievement is quite high for secondary school mathematics and science in South Africa (Maree, Aldous, Hattingh, Swanepoel & van der Linde, 2006; Ndlovu, 2011). In response, there has been a strand of research dedicated to investigate the factors that lead to poor learner attainment in mathematics and science (Cho, Scherman & Gaigher, 2014; Makgato, 2007; Maree *et al.*, 2006; Ndlovu, 2011; Visser, Juan & Feza, 2015; Howie, 2003). The various factors stem from the socio-economic status of the schools and learners, including historical and current conditions (Rhodes & Brudrett, 2009; Visser *et al.*, 2015; Govender, Grobler & Mestry, 2015). Internationally, benchmarks such as TIMSS have put learner performance in mathematics and science in the spotlight (Cho *et al.*, 2014; Ndlovu, 2011; Noyes, Wake & Drake, 2013). The accentuated attention given to national performances in mathematics and science is triggered by the perceived potential for growth of economies through the development of human capital in the science, technology, engineering and mathematics (STEM) fields (Clothey, Mills & Baumgarten, 2010). Learner attainment in mathematics and science has become one of the focal points in school improvement

efforts for high schools in some parts of the world (Noyes *et al.*, 2013). Due to the reduced learner performance in mathematics and science, it is common for school improvement plans to place more emphasis on these subjects (Mushayikwa, 2009). The position on learner attainment is backed by policies. For example, the master plan for total learner performance and school management improvement by the Eastern Cape Department of Education (2009, p.5) recognises the presence of 'killer subjects' in school curriculums. The 'killer subjects' are notorious for high failure rates and mathematics and science are included.

Similar to mathematics and science attainment, school leadership practices are influenced by socio-cultural and historical settings (Hallinger & Heck, 2010). There is a need for many schools to develop and enact effective school improvement plans in order to deliver on the core business of schools by meeting the requirements of the high-stakes testing in place. To this, van der Voort and Wood (2014) observed that many underperforming schools do not have operational school improvement plans. Meeting the requirements of high-stakes testing mechanisms is one way in which schools are held accountable for the work that they do with the learners (Thibodeaux, Labat, Lee & Labat, 2015). In South Africa, schools not only account for the whole school matric results each year but also the matric results for mathematics and science in particular. Consequently, Khupe *et al.* (2013) posit that the quest to sail through high-stakes testing such as matric examinations has given way to short term goal school improvement interventions that are 'narrow' and confined to the classroom. The primary focus of the interventions has been on teacher development, resource provision and learner support. Fleisch, Schoer, Roberts and Thornton (2016) however report of an improvement observed in numeracy skills during a system-wide improvement of early grade mathematics by using combined lesson plans, learner resources and quality teacher capacity building. Similarly, this study explored how leadership practices mediate school improvement plans for enhanced learner attainment in high school mathematics and science. For this study we ask, *how can schools construct instructional leadership practices that sustain mathematics and science learner achievements in high-stakes testing environments?*

LITERATURE REVIEW

We realise that while socio-historical factors are known to have enduring effects on schools (Rhodes & Brundrett, 2009; Msila, 2011) some school improvement plans bring about the desired change despite the perceived incapacitation. Similarly, McFarlane (2013) notes that some countries bestowed with more wealth, resources and technology, such as the United States, are often outranked in international benchmarks for literacy in science, mathematics and reading by poorer countries. Maringe, Masinire and Nkambule (2015) explored the reasons why some impoverished schools manage to achieve enhanced learner attainments despite their conditions. The study concluded that the improved learner attainments in the deprived schools were attributed to leadership practices that displayed an extraordinary focus on instruction, the availability of a stable human capital to provide instruction, parental involvement and school-wide projects that are a source of pride and inspiration. It can be surmised that the aforementioned factors hinge on leadership practices to provide vision and support for sustainability. Hallinger and Heck (2010) insist that leadership for school improvement is highly contextualised and each school follows its own improvement trajectory. Based on the discussions above and our own experiences, we observed that school leadership practices may not bring about the aspired change in learner attainment in the subjects of mathematics and science in the same way they do for the rest of the subjects in the school curriculum. Achievement in mathematics and science does seem to respond in a unique way to school improvement plans under prevailing leadership practices. The paper builds upon previous research on effective leadership practices for improved learner outcomes in the context of mathematics and science education.

Reports on school leadership practices describe a trend in which there is a new way of looking at leadership as a shared responsibility and not as the sole responsibility of the principal (Hartley, 2007; Lumby, 2016; Diamond & Spillane, 2016). However, principals still have an overarching influence to create cultures in which leadership roles may be shared. MacNeil *et al.* (2009) posit that

the school principals are responsible for creating effective schools through good cultures and climates that can bring about enhanced learner attainment. The emphasis in creating good school cultures and climates is on building healthy working relationships among the various stakeholders that include teachers, learners, parents and the community (Harris, 2003). The creation of healthy working relationships by principals includes the sharing of leadership roles with other staff members to enact school-wide actions for school improvement (Hallinger & Heck, 2010; Lumby, 2016). School leadership is increasingly being recognised from a distributed perspective due to the realisation that principal leadership does not account for all the processes leading to school improvement (Diamond & Spillane, 2016). This realisation makes distributed leadership a positive culture and climate to activate the leadership functions that stimulate school improvement processes.

High-stakes testing environments have been observed to influence school leadership practices (Thibodeaux *et al.*, 2015). Keans (2016) observes that high-stakes testing or standardised testing is currently a prevailing mechanism in many countries to test, monitor and improve school systems. Accordingly, they form quite a strong basis that stakeholders in education use to judge the performance of schools. Failure to achieve the expected progress results in punishments such as lower rankings (Myers, 2015). The school and all stakeholders wait eagerly for matric results every year because high-stakes tests are important for providing criteria used in certification and the subsequent selection and placement of learners who exit secondary school. They are particularly important in South Africa where high-stakes testing in the form of end of year results are used to determine grade retention or progression. It is only natural that considerable effort and attention are directed towards ensuring learner performance. Thibodeaux *et al.* (2015) posit that school leadership take desperate measures to meet the growth in learner attainment according to policy requirements and stakeholder expectations. Although William (2010) accedes that high-stakes testing is a cost-effective way of achieving the desired change in learner attainment, the author however points out that the system comes with unintended negative outcomes. The reported high failures in mathematics and science occur in the same high-stakes testing environments. It is only natural to wonder how they are affecting school improvement plans for mathematics and science.

THEORETICAL FRAMEWORK

Integrated model of school leadership

Hallinger (2003) asserts that there is no one school leadership model that can be singled out as the best practice to support school improvement. The reviewed literature that deals with the cultivation of school cultures and climates which translate into enhanced learner outcomes points to certain leadership functions that should be effective for learner attainment (Engels, Hotton, Devos, Bouckennooghe, & Aelterman, 2008; Rhodes & Brundrett, 2009; Hallinger & Heck, 2010; Msila, 2011; Maringe *et al.*, 2015; Govender *et al.*, 2015). The functions are closely linked to the typologies of school leadership outlined by Bush and Glover (2014). These are (1) instructional leadership where the focus is in managing teaching and learning, (2) managerial leadership where the focus is on functions and behaviours and (3) transformational leadership where the focus is on ensuring that teachers have high levels of commitment and greater capacities. Furthermore, (4) moral and authentic leadership where the focus is on integrity as informed by the values, belief and ethics, (5) distributed leadership where the focus is on shared leadership practices and (6) systems leadership which uses school clusters in order for teachers to learn from each other. Finally, (7) teacher leadership which recognises that teachers can execute leadership roles and (8) contingent leadership that provides insights into ways leaders respond to unique situations and problems. All of these models of school leadership should be implemented accordingly to support a holistic change and school improvement. We used the integrated leadership model approach as a lens to identify practices that supported enhanced learner outcomes.

METHODOLOGY

The study used a qualitative case study approach that used two schools that were selected using purposive sampling techniques. One of the high schools was selected because of the good learner

achievements in mathematics and science that had been recorded for the past five years. The other school was selected for the observed poor learner attainments in mathematics and science also recorded for the past five years. The information was obtained through word of mouth from the district offices. Data were collected in the form of narratives from principals, heads of departments (HODs) and teachers for mathematics and science. The narrative data were texts collected by means of relevant data collection tools (Creswell, 2007) in the form of semi-structured interviews and field notes compiled through unstructured observation. The semi-structured interviews which were one hour long elicited the school improvement trajectory as influenced by the school leadership practices by prompting participants to provide narratives of all that they considered relevant. The participants were prompted to narrate what they considered to be school leadership practices and other activities used to support mathematics and science learner attainments in the school. The unstructured observations captured relevant data such as was used in the description of the sample. Martin (2016) says that narratives bring forth stories in which the participants paint pictures of real experiences.

Sample

The study was conducted in a former Model C high school (high-performing in mathematics and science) located in a southern suburb in Pretoria and low-performing school in one township in Bloemfontein. Sampling was purposive in order to select sites that were data rich. We assigned the pseudonyms to the research sites as School P and School B respectively. Purposive sampling ensured the selection of data-rich research sites. Convenience sampling was further used to select the study participants who were willing to be part of the study. In School P, five participants that constituted the principal, the vice-principal, a science department head, a mathematics senior teacher and a physical science teacher were interviewed. In School B, we were only able to speak to the vice principal, the mathematics and science HOD. Our attempts to speak to the teachers were fruitless. School P had about 1800 learners (multi-racial), and 105 teachers. The Gauteng Department of Education did not employ all 105 teachers. Some of the teachers were on the school's governing body payroll. School B had 43 teachers (all on the Free State Department of Education payroll) and about 1000 learners.

Ethical considerations and quality measures

Ethical considerations were observed for this study. The study obtained an ethical clearance from the university. Further permission to conduct the research was solicited from the Gauteng Department of Education and the Tshwane South District before approaching the school and also from the Free State Department of Education. The use of a comparison approach between a high performing and low performing school was one of the ways to ensure the credibility and trustworthiness of the findings.

Data analysis

Creswell (2007) defines narratives as written or spoken texts describing events or actions that are chronologically connected in an individual's life. The content analysis was conducted in two steps. Firstly, we used the seven functions of leadership reflected by the typologies of leadership in Bush and Glover (2014) as an analytical framework to code the textual data according to an integrated model to school leadership. Secondly, we engaged in an inductive process of further analysing the findings from the first step through the constant comparison techniques to build themes of the instructional leadership practices that worked to improve learner attainments.

FINDINGS

The findings of this study are discussed under four themes which were (1) focused vision for mathematics and science attainment, (2) instructional leadership spread over several individuals, (3) data-driven decisions and school-based professional development and (4) making sense of the high-stakes environment.

Focused vision for mathematics and science attainment

First we analysed the envisaged mathematics and science attainment visions for the two schools. In School P, the vice-principal for academics (Grades 10-12) described the school as follows, “Well, we are the top maths school in Pretoria for the last five years. In maths we have few that do not pass but the school has an overall of 95 per cent pass rate”. We noted that it was expected of mathematics and physical sciences to have a lower percentage pass rate than the school average. School P mathematics teacher revealed that the school targeted to achieve an average percentage of 65% in mathematics. She said, “We work for 65 [per cent] more or less, and more”. The physical sciences teacher was of the opinion that there is a positive correlation between marks that learners obtain in mathematics and physical sciences. She remarked that “If you do have a kid getting a bad physical sciences mark you can always reference it back to the mathematics mark and it is gonna be the same”.

However, School B vice-principal was of the opinion that it was impossible for learners to do well in mathematics. She described the position of the school as follows,

Our position as a school is that we received a circular saying that our learners must do maths and this was in 2013. We were instructed that learners must do maths in grade 10 and we knew that it was not possible. So what we did was that learners who did services [consumer sciences] had to do maths lit [mathematical literacy] and learners who did physical sciences had to do pure maths. Those learners who do not cope with pure maths then we introduce them to maths lit.

The recommendation in the mentioned circular was affected only for Grades 10-11 as most learners would move to mathematical literacy in Grade 12. We were able to make the preceding claim from the following conversation with School B mathematics and science HOD.

Interviewer: Is there a choice of subjects in your school and at what Grade are learners able to make the choice?

School B HOD: In our school it works differently because all learners do pure maths [mathematics] till grade 11 and then in grade 12 that’s when they get to change on whether they keep doing pure maths or do they want to do maths lit.

Interviewer: How many classes do you have for math and maths lit?

School B HOD: We have more maths lit classes than maths. We split the classes whereby some are doing maths and others are doing maths lit.

As a demonstration of *transformational leadership*, School P envisioned that more learners should excel in mathematics and science. The school principal said,

We’ve got a specific vision that we want most of our learners to have the ability to take maths and science because we have very good teachers and we want to give them [learners] the best maths and science.

Instructional leadership spread over several individuals

In order to achieve its vision School P embraced *distributed leadership* practices to influence the mathematics and science school improvement processes. We observed the existence of academic committee constituted by two academic managers, the mathematics and science heads of departments (HODs), subject heads/teacher leaders and the principal as providing the leadership. The academic manager position (vice-principal in charge of the curriculum) was one of the six vice-principal positions in the school. The principal thought that the existence of an academic committee paved the way for good organisational processes for school improvement. He said,

We've got a good organisational structure what we call an academic committee. Those are only senior teachers in each field of study and then we got head of academics for the two phases and we got head of academics for the general phase and head of academics for grade 10, 11 and 12. They got a job description and we do a lot of analytical assessment regarding the outcomes of assessments according to that the HOD and the teacher co-coordinating the grade subject come up with improvement plans that must be implemented but also they must be assessed to whether they stick to improvement plans.

In contrast, instructional leadership was spread over less people in School B who were limited to the HODs, the principal and two vice-principals. The HOD was largely responsible for monitoring instruction for Grade 8-12. She said,

Every grade has its own work schedule that is Grades 8, 9, 10, 11 and 12. It is divided into term one up to four so when I check learners books I can see where the teacher is up to date with his/her work and then I look at that work schedule and check whether they are on board or not and if not I will call upon the educator and ask them if there are any reasons for not covering their work.

The School P HOD for science also revealed a system in which teachers were tasked with leadership responsibilities (*teacher leadership*). He said,

We got a system that senior teachers become leaders of the group so there's lot of stuff that they do. They check if the work is done. They set the standard for test and exams as well as how many they will be. I just moderate it.

Data-driven decisions and school-based professional development

The role of the HODs as articulated by principal in School P entailed facilitating *professional development and leading in inquiry processes* for improved learner attainment. Through subject meetings, HODs facilitated teacher learning. Learning challenges were also discussed as he said,

The HODs must do quality evaluation. They must do in-service training. They must do assessment and data analysis because I'm expecting them to identify where there is a problem, where they must improve... so I try to conduct administrative talks with the HODs at least because we are not having meetings of discussing the paper [exam/test papers]. That must be done in subject meetings. They must do something regarding a part of the curriculum, explain it and ask teachers to explain it... what methodology can be used and giving feedback in the form of quality evaluation.

In a demonstration of *managerial leadership*, the School P principal was also actively involved in the inquiry processes to determine teaching and learning problems. The School B mathematics teacher revealed that the principal followed the progress of every learner in the exam classes by analysing and discussing the learners' performance with the teachers. She said,

You have to make an appointment with him. We had to do it in the past holiday week. We had to finish our marking and then bring the SBA [school based assessment] marks to him so he went through each and every child's marks worked out the averages, spread tables.

Relentless focus on instruction

School P set in motion *instructional leadership* processes to improve learner attainment by emphasising instruction. The School P physical sciences teacher revealed that she has been conducting extra lessons every afternoon and during holidays for the exam classes. The focus on

extra instruction is partly to prepare learners for the high-stakes testing by using a compilation of past exam papers. She said,

I am teaching extra classes every day for the whole year after school so I can really say I have done my part. During the June holiday we did teach winter school where they pay extra for it. What I did is I compiled the last ten years' papers. I did the physics and my HOD does the chemistry so it's a book like this that I give to them [learners] with a memorandum so I revise on the day and the rest I give to them as homework.

In School B it was mostly the teachers' responsibility to make sure the learners do well in mathematics and science. What we say was surmised from the following interview excerpt.

School B HOD: If learners write a test and yet they did not understand the concepts and the work I general then they will fail and this will be the teachers' responsibility on why some many learners failed."

Interviewer: So you make sure that before they write they finish the syllabus?

School B HOD: We try to.

Making sense of the high-stakes testing environment

In making sense of the high-stakes testing environment the two schools differed in their approach to manage how the mathematics and science learner attainment contributed to the whole school performance. Based on the above evidence School P had a proactive vision to the promotion mathematics and science education. School B however diverted most learners from mathematics classrooms to mathematical literacy classrooms at Grade 12 so as to protect the school's general performance each year. School P made available more material and human resources to support the teaching and learning of mathematics and science than School B. The availability of a sufficient human resource base in School P enabled the spread of instructional leadership over several individuals. The availability of a substantial resource base enabled School P to relentlessly focus on instruction by providing an incentive for the teachers. School P also worked closely with the parents. The mathematics senior teacher revealed how the parents take a keen interest of what goes on in the school. He said,

Also we have a very active I can almost say over active community of parents. They don't hesitate to phone the school and tell the principal this and that, teacher X said this, did that whatever, we are always in the public eye.

One parent representative was on the curriculum committee of the school governing body (SGB). The parents were required to provide the school with support regarding some curriculum issues such as learner participation in assessment activities and other behavioural issues. The School P vice-principal said,

I don't think the parents can be involved in curriculum because the curriculum is prescribed, but we give them information on how assessment will be done and what is the scope of assessment and what needs to be done and if the kids do not hand in like the practical assessment tasks we communicate with the parent to give us help. I phone the parents to come to school and come see me especially when learners have learning and behaviour problems.

DISCUSSION AND CONCLUSION

Hallinger and Heck (2010) underscore the uniqueness of each individual school's school improvement trajectory. We conducted this study in order to identify some of the working constructions of instructional leadership. It may seem as if the disparities in the socio-economic status of the compared schools may have had a significant influence of the way instructional leadership

constructions. In fact, some literatures associate the schools' higher socio-economic status and affluent historical backgrounds with better chances of achieving enhanced learner outcomes (Cho *et al.*, 2014; Rhodes and Brundrett, 2009; Maringe *et al.*, 2015). However, more than twenty years after the dawn of the democratic dispensation in South Africa it is important to know what is working and what is not working so as to make the necessary recommendations. School leadership and governance are some of the targeted areas for school improvement in South Africa and these are most likely to fail in communities where the wealth and social capital are significantly lower (Khupe *et al.*, 2013). Accordingly, one of the recommendations would be for the responsible authorities to make available the material and human capital equitably to all schools. In spite of that obvious recommendation we still believed that we could highlight some of the practices in instructional leadership constructions for mathematics and science achievement in high schools. Accordingly, we observed a number of school leadership functions that we highlighted as working effectively for mathematics and science improvement. There was evidence of strong transformational leadership practices that were espoused by the school's vision for learners to excel in mathematics and science. One of the tenets of transformational leadership is the ability by school leaders to define a vision, fostering group goals and providing a model for school improvement (Govender *et al.*, 2015; Bush and Glover, 2014; Valentine and Prater, 2011).

A distributed leadership set up was put in place to drive and support the vision and the strong focus on instruction. An academic committee provided instructional leadership. A number of school leaders who actively exercised influence on instruction constituted this committee. These included the two academic managers who were the formal leaders for curriculum and instruction, the principal, the mathematics and science HODs and teacher leaders in the capacity of subject leaders in every grade. Valentine and Prater (2011) assert that transformational principals harness and utilise the expertise of other leaders and teachers in the school. Hence, the increasing recognition that enhanced learner attainments are attributed to and can be explained through distributed leadership practices (Diamond and Spillane, 2016). Functions focused on staff behaviours such as effectively organising tasks and personnel as well as evaluating teachers are accomplished through managerial leadership (Bush and Glover, 2014; Valentine and Prater, 2011). The HODs were responsible for evaluating the teachers and in turn, the academic manager evaluated them. However, the exam class teachers had one-on-one accountability sessions with the principal. These exercises were directly influenced by the school leadership's concern and quest to perform well in the high-stakes testing.

Moreover, the school actively engaged the community of parents. Parents were expected to monitor their children's participation in assessment activities thereby becoming directly concerned about their children's attainment in the various subjects. Strong community engagement and parental involvement are vital in supporting school improvement plans (Maringe *et al.*, 2015; Khupe *et al.*, 2013). Consequently, the strong focus on instruction by the school through the provision of resources, extra teachers paid by the SGB as well as extra and vacation classes could be sustained.

We would also like to highlight that schools were faced with tensions under high-stakes testing environments of whether to provide mathematics and science tuition to learners up to Grade 12 or divert them to other subject electives in order to protect the schools' average pass rates. School B did not believe that learners could do well in mathematics and science. High failure rates are characteristic of high school mathematics and science in general (Maree *et al.*, 2006; Ndlovu, 2011). These previously mentioned tensions are significant in the drives to promote mathematics and science education and partly explain the reduced numbers of learners who enter universities with mathematics and science in South Africa according to Maree *et al.* (2006) and Ndlovu (2011). In conclusion, the identified instructional leadership constructions and cultures that are effective for enhanced learner attainments in high school mathematics and science should be accessed by all schools despite their historical background and context.

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IDENTIFYING AT-RISK STUDENTS IN A STATISTICS COURSE THROUGH A MATHEMATICAL MODEL

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ABSTRACT: In this paper, we report on the identification of at-risk students in a Business Statistics course through an appropriate mathematical model. Early prediction for students that are at-risk of failing statistics courses seems necessary to enhance academic success in formal tertiary education. Statistical knowledge is included in a variety of programmes offered over many faculties at tertiary level, but students are not necessarily well prepared for these courses, or foster positive attitudes towards such courses. In addition, they mostly find the content difficult. These, and other contributing factors, result in unsatisfactory throughput rates. Lecturers, and more broadly faculties and universities, are increasingly expected to keep academic standards and improve academic success. In this study, we used 480 Business Statistics student's grades from the first quarter of an academic semester at a public university in South Africa to build a predictive model to identify at-risk students. Model construction was based on six evaluation criteria: accuracy, realism, precision, robustness, generalizability, and fruitfulness. These results could inform lecturers, early in the academic semester, of statistics students who are more likely to fail the course than pass the course, which could lead towards instructional practices to support these students. Furthermore, the effectiveness of such a model to predict students' academic success is investigated.

Keywords: Academic success; at-risk students; predictive modelling; teaching and learning statistics; tertiary education.

INTRODUCTION

Research results published by The Centre for Development and Enterprise in South Africa (SA) confirmed a significant under-performance in education at school level, particularly in mathematics teaching and learning (Bernstein, 2013). At tertiary level, a clear distinction exists between statistics education and mathematics education, but in the current SA context, statistics forms some part of the mathematics school curriculum. Bernstein's report (2013) underlined three key factors, among others, that are noteworthy for the teaching and learning of mathematics (that also includes the teaching and learning of statistics), namely (i) poor mathematics teachers' competencies (related to content and pedagogy); (ii) poor mathematics students' competencies; and (iii) a large gap in mathematics competencies among school students from the lowest income areas (approximately 66% of the population) and those from the richest areas. These results suggest a large number of SA students, who enter formal tertiary education, might be under-prepared for mathematics related courses, such as statistics.

Learning statistics involves an integration of a first "statistical literacy" component, a second "understanding and using the basic language and tools of statistics" component, and a third "statistical reasoning" component (Garfield & Ben-Zvi, 2007, pp. 380-381). Garfield and Ben-Zvi (2007) emphasised that statistics students' understanding of the basic concepts of statistics can easily be underestimated or overestimated by the educator. In this inquiry, we argue every student can learn statistics and attain the necessary skills for academic success – the focus should be to meet the students' needs and not the incapacity of students.

Almost three decades ago, an *at-risk* student is defined as "one who is in danger of failing to complete his or her education with an adequate level of skills" (Slavin & Madden, 1989, p. 4). Educators often view at-risk students as the ones who are more likely to fail than pass the course. A broad overview of

the literature revealed numerous studies on students' lack of academic success or delay during formal tertiary education, particularly in numeracy related fields, and a number of contributing factors (Cassidy, 2015; Onwuegbuzie, 2004). Some of these contributing factors are the lack of self-efficacy, statistical anxiety, fostering negative attitudes towards statistics courses and students finding statistics content difficult (Coetzee & van der Merwe, 2010; Onwuegbuzie, 2004; Talsma, Schüz, Schwarzer, & Norris, 2018; van Appel & Durandt, 2018). In addition, Science and Engineering courses generally obtain lower pass rates than many other courses at tertiary level, making it very important to be able to support students in need. Within the SA context, educators (lecturers, faculties and universities) are continuously more strained to increase pass rates and at the same time present students with a quality course. It seems therefore essential to identify the needs of students as early as possible to improve instructional practice. However, the focus of this inquiry is to identify at-risk students in a statistics course at a public university in SA, and not to improve instructional practices.

The two research questions are: (1) what is a predictive mathematical model used to identify at-risk students in a Business Statistics course at tertiary level, and (2) how effective is such a model to predict students' academic success in this course? In answering these research questions, we attempt to broaden our knowledge about the identification of at-risk students in a statistics course as early on as possible in the academic semester. These results could contribute towards promptly detecting the needs of at-risk students, and ultimately resulting in improved instructional practices and throughput rates in statistics.

THEORETICAL PERSPECTIVES

Theoretical framework

The Russian psychologist, Vygotsky's 1978 notion of the Zone of Proximal Development (ZPD), grounds this inquiry. The most widely known definition of ZPD is "the distance between the actual developmental level, as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 33). Hence, in ZPD, potential developmental levels between unassisted and assisted directives is highlighted and this notion serves as a motivation to support statistics students on their journey to independence, as their understanding of statistics becomes more secure. This framework provides a theoretical base for the need to identify at-risk students.

Wertsch (1985), as cited by Goos (2004), acknowledged three claims from Vygotsky's work from a Western perspective that were applicable to this inquiry, namely that (i) an understanding of mental function occurred via a process of growth and change rather than as a result of a focus on the product of development – this claim demonstrates the need to identify at-risk students as early on as possible to ultimately provide structured support during their formal education; (ii) mental functions, such as memory, concept and reasoning (apart from others) originated from the social interaction among both educators and students – this claim demonstrate the need to identify the needs of at-risks students; and (iii) mental processes were assisted by tools such as language, writing, counting and algebraic systems, geometrical experiences, diagrams, and others – this claim demonstrates the under-preparedness of students for tertiary education (specifically related to a SA context) could delay the development of mental processes (also see Mix & Cheng, 2012).

In summary, we argue that the notion of ZPD inform students' learning in statistics and every student can attain the necessary skills for academic success when formal education meets the students' needs and not the incapacity of students.

Models and teaching

Doerr, Ärlebäck & Misfeldt (2017, p. 71) underscored the substantial impact of mathematical models at all levels of society by claiming that "mathematical models are used to control processes, to design products, to monitor and influence economic systems, to enhance human agency, and to structure and understand the natural world in society and above all in the workplace". In the context of this study,

we used a mathematical model to identify at-risk students in a Business Statistics course as early as possible in the academic semester. Thus, the emphasis was on the product and its efficiency, as it would play a role in decision-making in the education context. Meyer (2012, pp. 150–222, originally published in 1984), proposed six evaluation criteria for mathematical models, namely (i) accuracy; (ii) realism; (iii) precision; (iv) robustness; (v) generalisability; and (vi) fruitfulness. We purposefully considered the criteria: (i) *accuracy*, if the output values were correct or near correct; (ii) *realistic*, if the model is based on correct assumptions; (iii) *precise*, if its predictions were in definite numbers, and imprecise, if its predictions were in a range of numbers; (iv) *robust*, if the model is to some extent protected against errors in the input data; (v) *general*, if it applied to a variety of educational contexts; and (vi) *fruitful*, if it resulted in useful conclusions. In this study we used a predictive model for a first-year Business Statistics course, but such a model can easily be adapted and used in other courses, given that there is enough reliable data available to ‘train’ the model.

RESEARCH DESIGN

This inquiry relates to the identification of at-risk students in a Business Statistics course through an appropriate mathematical model, conducted from a *post-positivist* worldview in seeking real-life solutions (Creswell, 2013) to an education problem. Data collected from 480 students in a first year Business Statistics course offered at the University of Johannesburg (UJ) in the first semester in 2017 were used. All students were studying on a full time basis. The participants and course were selected based on current undesirable throughput rates. The gradebook reflected students’ statistics marks collected throughout the semester by means of multiple assessment opportunities. These assessment opportunities consisted of weekly online quizzes and two formal semester tests, all accumulating to the *final period mark* (FPM). At the end of the semester, students wrote an *examination* (EM). Both the FPM and EM contributed in equal parts to students’ *final mark* (FM). To pass the statistics course students’ required a FM greater or equal to 50%.

A mathematical predictive model uses statistics to predict outcomes. More specifically, in this case, we used the past students grades to identify patterns or trends to build a model that could predict the current student’s grades. The predictive power of these mathematical models is very much reliant on the covariates (also commonly referred to as independent variables) too accurately describe the data. Bainbridge, Melitski, Zahradnik, Lauría, Jayaprakash and Baron (2015) studied certain demographic, educational and behavioral patterns in search of worthy covariates to predict at-risk students in an online Masters of Public Administration program. For example, they studied the influence the number of times a particular student logged into their course through the student portal, or the participation of the student in online forums, to predict at-risk students. In addition, they revealed that these behavioral factors, along with more traditional covariates, such as overall grade point averages, performance on assignments, class size and age, could predict at-risk students more accurately.

It must be noted that there is most certainly different challenges involved in identifying at-risk students in, for example, a first year course compared to a third year course, or a course in life sciences compared to a course in mathematics, or a face-to-face course compared to an online course. The different challenges are likely to be subject, content or design specific and require some insight from the educator in deciding how these differences can be incorporated to construct a useful predictive model. Furthermore, it would be ideal if a predictive model for a specific course is continuously revised to improve its usability.

STATISTICAL ANALYSIS AND RESULTS

Predictive model

To develop a predictive model to identify at-risk students in a statistics course, we used two covariates, namely the average quiz mark (calculated from the first six quizzes) and their first semester test mark. We used the data available from week 6 in a 14-week academic semester to construct a model. The implementation of a predictive model early on in an academic semester will allow more time to support at-risk students. However, this will come at an accuracy cost, as there will be less information

available to ‘train’ the model. The course outline for the statistics course is displayed in Table 1. Implementing a predictive model in week 6, will allow educators on the one hand enough time to assist at-risk students in this course without largely compromising the accuracy, and on the other hand, it allows enough information to ‘train’ a model.

Table 1. Course outline of the Business Statistics course from week 1 – 14

Week	Quiz	Semester Test	Content
1	1		Data types, Measurement scales, Population vs Sample
2	2		Graphical Representations of Data
3 & 4	3 & 4		Numerical Descriptive Measures: Measures of center & spread
5 & 6	5 & 6	1 (week 6)	Introduction To Probability
7 & 8	7 & 8		Binomial Distribution & Poisson Distribution
9 & 10	9a & b		Standard Normal Distribution & Normal Distribution
11	10		Simple Linear Regression
12	11	2 (week 12)	Index Numbers
13 & 14	12a & b		Time Series

In Table 2, we display the Pearson’s correlation coefficients for the covariates with students’ FM. Similar to Marbouti, Diefes-Dux and Madhavan (2016), we will accept a Pearson’s correlation coefficient of 0.3 or higher as acceptable covariates.

Table 2. Pearson correlation coefficients between covariates and FM

Covariate	Pearson Correlation Coefficient
Average quiz mark	0.3293
Semester test 1 mark	0.4863

In addition, the accuracy of the predictive model will be analysed as follows (compare Marbouti et al., 2016):

- $Accuracy = \frac{True\ Negatives + True\ Positives}{Total\ number\ of\ students}$
- $Accuracy\ (Pass) = \frac{True\ Negatives}{Number\ of\ passed\ students} = \frac{True\ Negatives}{True\ Negatives + False\ Positives}$
- $Accuracy\ (Fail) = \frac{True\ Positives}{Number\ of\ failed\ students} = \frac{True\ Positives}{True\ Positives + False\ Negatives}$
- $F_{1.5} = \frac{(1+1.5^2) \times True\ Positives}{(1+1.5^2) \times True\ Positives + 1.5^2 \times False\ Negatives + False\ Positives}$

Where:

- *true positives* is the number of students that failed and where identified as at-risk,
- *true negatives* is the number of students who passed the course and where not identified as at-risk,
- *false negatives* (also known as type II error) is the number of students who failed the course but were not identified as at-risk students,
- *false positives* (also known as type I error) is the number of students who passed the course but were identified as at-risk students, and
- $F_{1.5}$ denotes the harmonic mean of precision and recall. More specifically, the harmonic mean takes into account the accuracy for the students who passed and failed the course, where it

weights the accuracy for students who failed more than students who passed (Van Rijsbergen, 1979).

Currently, we identified students as at-risk in this course if they obtained less than 50% for semester test 1 (we will refer to this as the base model). Later, we will show that this model does not yield accurate predictive results. Therefore, in search of an accurate predictive model we will implement two alternative predictive models, namely,

- *Multiple Regression*: Multiple linear regression generalises simple linear regression by allowing for multiple independent variables.
- *Logistic Regression*: Logistic regression is a commonly used prediction method used in predicting at-risk students (see e.g., Brainbridge et al., 2015; Marbouti et al., 2016). Logistic regression calculates the odds of observing a binary variable (0 – fail and 1 – pass), using a number of covariates (independent variables).

Both these predictive models are easily implemented in many statistical packages, making them suitable models to predict at-risk students.

Statistical results

Figure 1 displays each student’s outcome for the course (i.e., pass or fail), with their average quiz mark (denoted on the x-axis) and semester test 1 mark (denoted on the y-axis). A number of students performed well in their first six quizzes and first semester test, but still failed the course. Similarly, some students performed poorly in their first six quizzes and their first semester test, but managed to pass the course. It is an almost impossible task to accurately predict all students’ final outcome for the course, as no model is faultless. Nevertheless, we can continue improving the model over time. Some contributing factors to the difficulty of this task is that the student’s behavior is seldom the same throughout the semester (see Marbouti et al., 2016). For example, in this study, many students did not write semester test two or stopped attending lectures due to financial constraints.

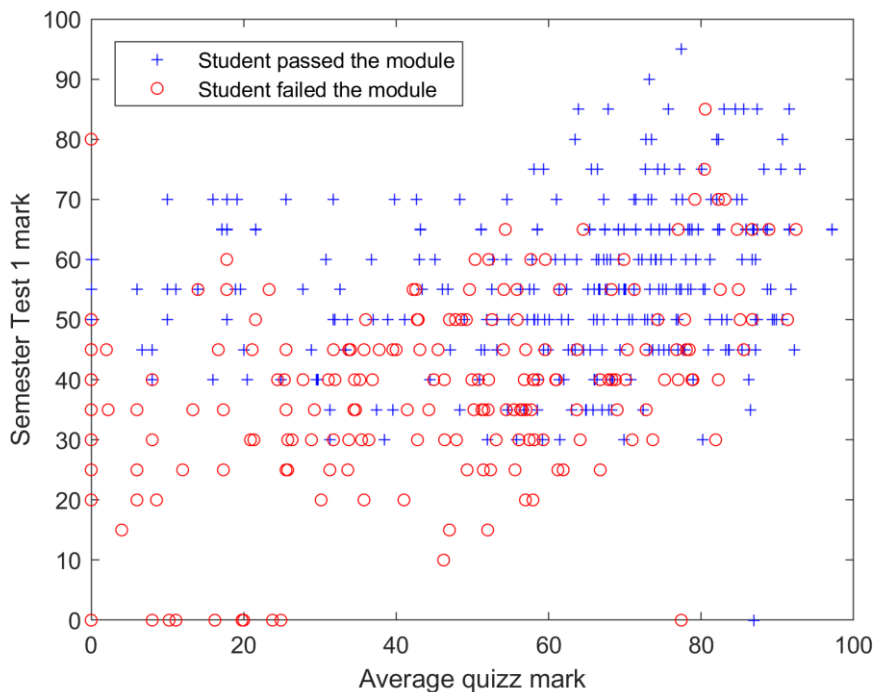


Figure 1. Relationship between average quiz mark and semester test 1 mark

Table 3 shows the results for the three predictive models used in this study. A good predictive model should yield few *false positives* and *false negatives*. More specifically, there is a higher consequence for

the *false negative* category (i.e., to identify a student as not at-risk, but the student should have been identified as at-risk), where there is little consequence for the *false positives* category (i.e., to identify a student as being at-risk, when the student is not at-risk).

Table 3. Predictive accuracy

Method	Base Method	Logistic Regression	Multiple Regression
$F_{1.5}$	8%	66%	72%
Accuracy	62%	76%	73%
Accuracy-Pass	100%	84%	71%
Accuracy-Fail	6%	63%	76%
True Negative*	285 (59.4%)	241 (50.2%)	202 (42.1%)
False Positive*	1 (0%)	45 (9.4%)	84 (17.5%)
False Negative*	183 (38.1%)	71 (14.8%)	47 (9.8%)
True Positive*	11 (2.3%)	123 (25.6%)	147 (30.6%)

*The number of students (out of 480) with the percentage shown in parenthesis.

Clearly, the base method performed poorly with a $F_{1.5}$ score of 8% and an overall accuracy of 62%. In addition, it yielded a large number of *false negatives*, and only correctly identified 11 students as at-risk out of 194 students that failed the course. Recall, there is a larger consequence in not identifying a student as at-risk when the student should have been identified as at-risk (i.e., *false negatives*). This is evident in the low $F_{1.5}$ score for the base method. Since this model has, a low accuracy in identifying at-risk students renders this model impractical, as no intervention program for at-risk students could be meaningful. The logistic regression and multiple regression models yielded far superior results with $F_{1.5}$ scores of 66% and 72%, respectively and an overall accuracy of 76% and 73%, respectively. In addition, both models yielded lower *false negative* and *false positive* outcomes, making these two models superior to the base model. Furthermore, the logistic regression correctly identified 123 students as at-risk out of the 194 students that failed the course. Similarly, the multiple regression correctly identified 147 students as at-risk out of the 194 students that failed the course. Thus, the logistic regression and multiple regression models are feasible prediction models for at-risk students.

More specifically, both the multiple and logistic regression models satisfied the six evaluation criteria previously discussed, since both models (i) yielded more accurate results; (ii) are realistic and viable as the data required to construct these models are relatively easy to collect and to implement in most statistical packages; (iii) yielded precise predictions (i.e. pass or fail); (iv) are known to be robust with extensive literature available to test the robustness of these models (although this is beyond the scope of this inquiry); (v) have successfully been used to predict at-risk students in this Business Statistics course, and (vi) yielded useful results which will allow educators to identify at-risk students.

Further research could investigate the robustness of these models. It would also be interesting to see how class attendance relates to academic success or failure of students in a statistics course. However, it is challenging and time consuming for lecturers to take registers in large classes, where many students do not have electronic devices available for recording. In addition, both the logistic regression and multiple regression models identified more than 120 students as being at-risk of failing the course. These large numbers could place strain on lecturers to provide sufficient support for students, and should be considered in curriculum planning. An effective intervention programs for at-risk students could be a valuable contribution following from these results.

CONCLUSION

In this study, we developed a predictive mathematical model to identify at-risk students as early as possible in a Business Statistics course at a public university in SA. Quantitative data were collected from the Business Statistics students' grades in the first quarter of an academic semester to answer the two research questions: (1) what is a predictive mathematical model used to identify at-risk students in

a Business Statistics course at tertiary level, and (2) how effective is such a model to predict students' academic success in this course? In answering these two research questions, we implemented three predictive models, commonly found in the literature and compared the accuracy of the models. Aligned with the notion of Vygotsky (1978), the *Zone of Proximal Development*, and the evaluation criteria of mathematical models (compare Meyer, 2012), we identified both the logistic regression and multiple regression models as viable predictive models. The results obtained from both these models could inform educators early on in the academic semester of *at-risk* students that requires support in the learning of statistics, to improve throughput rates without compromising academic standards. To consider for further inquiry is additional criteria to improve the mathematical model efficacy in identifying at-risk students in Business Statistics, as well as generalising the applicability of the model to other subject domains.

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TSHIMOLOGO: A NEW DAWN FOR SELF-DIRECTED LEARNING AND MATHEMATICS EDUCATION

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ABSTRACT: This paper reports on the first phase of a project which still needs to be implemented. The project builds on a Short Learning Programme (SLP) in Ethno-mathematics, developed and presented in three provinces in South Africa (2016-2017). The goals of the SLP were to introduce mathematics teachers to viable ways to teach mathematics in a more contextualised way (e.g. through the introduction of indigenous knowledge) and develop teachers' pedagogical content knowledge (PCK). One such way was to introduce these teachers to the Mathematics Shoestring Kit (MSK). The researchers developed this kit which contains music instruments (boom whackers), indigenous games (Morabaraba) and handmade puppets accompanied by a guideline booklet – all overlapping with mathematical themes. The MSK was developed to assist in the transfer of mathematical knowledge, developing teachers' metacognition and self-directed learning. The reason for developing teachers' metacognition is to improve the application of knowledge, skills and affective qualities in realms beyond the immediate context in which they were trained. Research on mathematics teachers' transfer of knowledge by applying a pedagogy of play (PoP) in their classrooms -using the MSK- after they have been introduced to and trained in such pedagogies is the main aim of this envisioned project in order to develop teachers professionally.

Keywords: Metacognition; mathematics shoestring kit; pedagogy of play; pedagogical content knowledge; short learning programme; teacher professional development

INTRODUCTION

The achievement and interest in mathematics in South Africa is low (Venkant & Spaul, 2015). Many teachers lack a nuanced pedagogical knowledge. If Albert Einstein views art as the highest form of hope and play as the highest form of research, the approach to teaching should change too.

CONCEPTUAL FRAMEWORK

Achievement and interest in mathematics among South African learners is low, and mathematics is widely despised because of school experiences: learners are made to feel bad in mathematics classes and do not enjoy school as they are made to sit through uninspiring lessons (Gafoor & Kurukkan, 2015). A reason that is often overlooked for the dismal performance in mathematics, is the fact that the affective domain of human thinking and reasoning is marginalised in mathematics education. Recent research (Dubinsky, Roehrig & Varma, 2013) shows that experiences with an emotional stamp become committed to memory which attributes to these negative experiences. The traditional mathematics teachers' transmission-mode teaching and learning is not appropriate to prepare learners for a complex 21st Century. Many individuals are receptive to the idea of a future in which all can learn mathematics based on a different teaching-learning approach. For example, the use of puppetry by teachers has been found to be effective in expanding the role of traditional teaching, changing teaching patterns, reflective observation of the educational process and professional development (Keogh, Naylor, Maloney & Simon, 2008; De Beer, Petersen & Brits, 2018). The advent of new technologies results in individuals being able to reason mathematically in order to work and live in today's society (Boaler, 2015). These changes pave the way for the creation of mathematics classrooms in which learners are excited to learn and teachers are armed with the most important knowledge and skills that inspires learners to achieve excellence in mathematics (Boaler 2015). The changing scenario, alters the teachers' dynamic demands and requires adaptation and integration of pedagogies that respond to a teacher's profile which understands the multidimensionality of the world and of human beings, as well as transforms their attitudes towards their learners' learning (Narvaja & Jaroslavsky 2004).

Most teachers lack well-defined ways to improve their teaching-learning in maths (How to Make a Good Teacher, 2016). Ball (2005) argues that teachers cannot be expected to know or do what they have not had opportunities to learn. Therefore, a need for professional development of mathematics teachers is necessary. Teachers' lack of adequate training in a variety of pedagogies that allows for its implementation (especially in the lower grades where the foundations in mathematics are laid) has become an increasing concern in educational reform.

The challenge for harnessing play for advancing lower grade learners' learning raises many questions such as: Can they learn through play? The gap is that these questions have not been addressed for learners in grades 4 to 9 in mathematics. This research project argues that contextualised mathematics using a pedagogy of play (PoP) and the mathematics shoestring kit (MSK), could serve as a very good entry point into the abstract world of mathematics. By linking mathematics to everyday experiences of learners (by applying games/music/puppets), might result in more affective engagement, and eventually more meaningful mathematical learning (De Beer, 2016). During the SLP teachers are assisted in their professional development to incorporate a pedagogy of play, whereby learners do mathematics in *Homo ludens* (the playing human) mode (Huizinga, 1955).

Pedagogy of Play

Lev Vygotsky (1967) identified play as the leading source of development in terms of emotional, social, physical, language, or cognitive development. Play has been described as a context in which learners can integrate experiences and understandings, draw on their past experiences, make connections across experiences, represent these in different ways, explore possibilities and create meaning (Bennett, Wood, & Rogers, 1997). If mathematics is as much about understanding connections, processes and possibilities as it is about knowing facts, then play and mathematics have much in common (Dockett & Perry, 2008). Learning through play is done easily, without fear of obstacles, and the knowledge acquired is assimilated and not forgotten for a long time (Bennet et al. 1997).

We draw on some of the commonalities between play and mathematics: social interactions underpin mathematical thinking; children's play can be very complex; develops and evolves over several days, weeks or even longer; often requires negotiations about roles, rules, materials and scripts. When mathematics lessons mathematical ideas are deliberately embedded in the PoP and in real life contexts/experiences of learners, they provide a sense of purpose and relevance for learning mathematics in terms of the development of western mathematical understanding (Ainley, Pratt & Hansel, 2006). In respect of this planned project, PoP includes music, games and puppetry which will be discussed next.

Music: Maths and music plays different roles in society and overlap in all kinds of interesting ways. However, mathematics is characterised as rational and abstract: the impression of numbers, calculations, algebra, proofs taught at school and is accompanied by feelings of rejection, anxiety and disinterest. By including music, affective outcomes could be effectively addressed in the classroom. An example that forms part of the MSK is 'boomwhackers', which is an effective way of teaching the learners fractions (refer to Figure 1).



Figure 1: Learners can master fractions in the mathematics classroom by making music using boomwhackers.

Games: Games have been part of the social fabric of many African societies for hundreds of years. Games, are being seen as learning spaces: they enable players to develop non-cognitive (affective) skills, such as patience or discipline, which are important for career and life success. De Beer (2014) refers to the affective domain as the “missing link” in STEM education. Games engage learners on a different level that can enhance attitudes towards mathematics by creating fun and enjoyment for learners and increase cognitive learning capabilities in mathematics and play a positive role in the social development of any individual (Bayeck Hristova, Jablokow & Bonafini, 2018). According to Mosimege and Ismael (2004), the potentialities of non-western games have not been explored so far and have not been documented at all. Mosimege and Ismael noted that indigenous games should be considered in their entire context (historical, social and cultural), which is possible to find and use appropriately. Morabaraba (Sesotho) (Umlabalaba Xhosa), as it is known in South Africa belongs to the class of three-in-a-row board games. Mosimege and Ismael (2004) identified mathematical concepts by the analysis of Morabaraba board: various quadrilaterals; ratio and proportion between the lines; and symmetry. Teachers are appropriately placed with their mathematical knowledge to translate the learners’ knowledge into meaningful mathematical explorations.

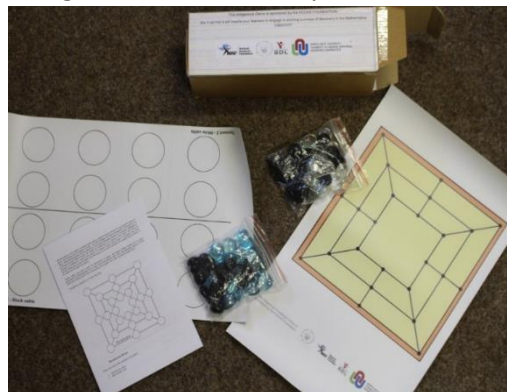


Figure 2: Games such as morabaraba holds affordances for Mathematics teaching and learning.

Puppetry: For hundreds of years puppets have been used as an important tool for teaching and learning and are located in the fine distinction between entertainment and learning. Through puppets, it is possible to communicate with a wide age range, diverse cultures and various language registers; through puppets, it is possible to influence children, who are considered "hard to reach" in the usual manner (Peck 2005). Mediation, using puppets, facilitates learning processes. De Beer et al. (2018) show that puppetry could facilitate conceptual change of learners. These authors are of the opinion that conceptual change should be viewed through a “warm” lens. This means that human emotions, worldviews and belief systems, all of which are addressed during puppetry, influence how conceptual change occurs.



Figure 3: Puppets hold affordances in the Mathematics classroom (Photograph used with permission of the student teachers).

Metacognition

Metacognition has important implications for the pedagogical practice, especially regarding teacher learning and the ability to teach metacognitive strategies to learners (Narvaja & Jaroslavsky 2004). Metacognition, simply put, is the process of thinking about thinking (Flavell, 1979). It is important in every aspect of school and life, since it involves self-reflection on one's current position, future goals, potential actions and strategies, and results.

Literature on metacognition commonly notes the importance of planning, monitoring and evaluation (Cheriyana, 2015). Self-directed learning underpins these dimensions by allowing teachers to take control in order to plan, implement and evaluate teaching-learning situations (Shannon, 2008). Therefore, metacognition can be viewed as the 'engine' that 'drives' self-directed learning. Metacognition advocates awareness among teachers to plan the teaching-learning situation while keeping clear goals in mind. Clear goals facilitate efficient monitoring of the teaching-learning process, ensuring the teacher is on track. Lastly, teachers evaluate the task relating to the accomplishment of the initial goal and search for areas for improvement (Okoro & Chukwudi, 2011; Douglass & Morris, 2014; Scharff, Draeger, Verpoorten, Devlin, Dvorakova, Lodge & Smith, 2017).

A metacognitive process, which gives the teacher the opportunity to think about how to learn, how to teach, with a view to redefining their pedagogical practice and their perception as researcher of this practice, is proposed. (Narvaja & Jaroslavsky 2004). Perhaps the most important reason for developing metacognition is that it can improve the application of knowledge, skills, and character qualities in realms beyond the immediate context in which they were learned, which can result in the transfer of competencies across disciplines (Schraw & Moshman 1995). The envisioned project aims to provide a framework sustaining metacognitive processes for professional development of mathematics teachers where a community of practice (CoP) is fostered. In these CoP's, reflection on own skills, limitations in planning, monitoring and evaluating teaching practices with peers are valued (Narvaja & Jaroslavsky 2004).

Teacher professional development

There is a need in South Africa for mathematics teachers' professional development. The project aims to provide grade 4 to 9 mathematics teachers the opportunity to implement a PoP using music, games and puppets, and developing lessons within a supportive community of practice (CoP) and become reflective researchers regarding their own teaching practices. A CoP between teachers and the understanding of the learning of teachers and the support of external tutors are important requisites for professional development, emphasizing that the school environment is the best place for teacher's professional development (Narvaja & Jaroslavsky 2004). A space for professional development is provided within the CoP, so that teachers can talk, listen, discuss and learn with their peers (Zapelini, 2009).

It also provides an opportunity for them to look at themselves, reflect on their professional performances and how they present themselves in the educational environment in which they operate. The importance of reflective practice makes indispensable the involvement of teachers as

"active participants in their learning, focusing their attention on critical elements, encouraging abstraction of themes or common procedures and allowing them to assess their own progress towards understanding" (Bransford Brown, & Cocking 2007, p. 97). As shown by Portilho and Medina (2016), a reflection on the teaching action itself is the most promising way for teachers to efficiently and effectively regulate their teaching strategies and can thus get closer to the goal of "teaching to learn".

THEORETICAL FRAMEWORK

This research is underpinned by social constructivism as theoretical framework. Cultural-Historical Activity Theory (CHAT) was developed by Vygotsky (1986) from Leontyev's (1978) thoughts and ideas. Culture and history became important factors when trying to understand and sustain development and learning. Third-generation Cultural-Historical Activity Theory as introduced by Engeström (1987) will be used as a research lens to research teachers' experiences of engaging with these innovative pedagogies. CHAT focuses on both the affordances and tensions that develop within an activity system. An activity system (see Figure 4) consists of the subject (mathematics teachers grades 4 to 9); the object (teacher professional development); suitable tools (PoP and MSK) to achieve the object (teacher professional development); outcomes (improved teaching-learning practice), rules (tenets of mathematics education, the CAPS curriculum, guidelines for using PoP and MSK), the community (facilitators, school, principal, teacher colleagues, surrounding school community, and teacher educators), the division of labour (where the teacher act as a mediator of learning, is a critical reflective practitioner, an artist and an agent of change). Here, CHAT acts as a barometer of tensions (which prevent the implementation of the PoP in mathematics education). Artefacts (puppets/games/music) play a mediating role in Third-generation Cultural-Historical Activity Theory. The participant teachers' PCK will be scaffolded in this research project (from a CHAT perspective) by improving their teaching practice (PoP), and enhance their metacognitive awareness.

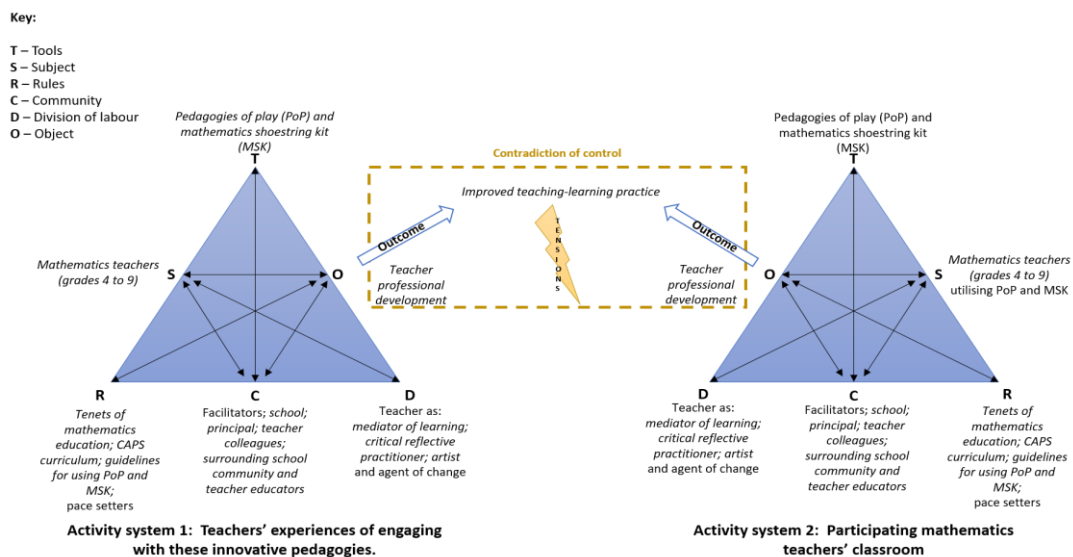


Figure 2: The CHAT lens that will be used in this research

RESEARCH METHODOLOGY

This research study will be conducted over a three-year period within the framework of a qualitative inquiry, and quantitative data will mostly be used for biographical purposes (Creswell 2009). It requires data relating to real-life contextual understandings, multi-level perspectives and cultural influences. Vianna and Stetsenko (2012) contends that people develop and learn as they actively participate and engage in the world they live in (teaching maths, PoP, CoP). Given the real world nature of teaching in context, the use of CHAT as a lens will provide understanding and enhancements for improving continuing teacher professional development in the field of teaching mathematics. Two universities (NWU and UFS) will be involved. Five primary investigators as well as one international co-investigator will conduct the research. Analysis of the literature review provides the theoretical

foundations for a set of design principles for the development of maths lessons. Using the first iteration of the design principles, mathematics lessons will be developed and piloted in classrooms. The results of the first design cycle of the study feed back into the theoretical foundations of the research, leading to the refinement of the design principles (Bray & Tangey s.a.). Using a lesson study approach to engage teachers (CoP) in developing and improving contextualised maths lessons are directed towards performance of learners at school level.

Population and sampling

Population: Primary and secondary schools will be invited to participate in the project in North-West Province or the Free State.

Sampling: Primary and secondary school mathematics teachers (grade 4 to 9) will be invited (N=79). Convenience sampling will be used to minimise logistical problems.

Data collection instrument

Determining teachers' (i) views of mathematics (Adapted Views of mathematics, Seldon & Seldon, 1996) (ii) self-reported metacognitive awareness (adapted MAIT/Metacognitive Awareness Inventory for Teachers, Balcikanli, 2011); and (iii) adapted self-reported self-directedness (SRSSDL/ Self-reported Scale for Self-directed learning, Williamson, 2007) questionnaires prior to and after the interventions will be used to determine how this project enhances teachers' views of mathematics, its teaching and learning; their metacognitive awareness and self-directedness [Determining how the nature of a lesson study community of practice approach facilitate teachers' PCK, metacognitive awareness and self-directedness].

The following data collection instruments will allow for an in-depth study over the three years, of teachers' professional development: including (but not limited to these) their knowledge of local IK and real life contexts of learners; their skills to plan and apply (transfer to their own classrooms) contextualised maths lessons in a CoP; the new pedagogies they were introduced to:

- ii. Individual and focus group interviews (lesson study participants);
- iii. Observation of lessons using the Reformed Teacher Observation Protocol (RTOP) instrument (Sawada et al. 2002);
- iv. Video-recording of lessons – for sharing and reflection with the other members of the lesson study CoP;
- v. Field notes (observations of lesson study activities or lesson beings taught or reflected on); and
- vi. Participants' reflective journals and
- vii. Lesson plans & CoP's portfolios.

Data analysis

Data will be analysed by applying the Statistical Package for the Social Sciences (SPSS), Transana and Atlas.ti software. NodeXL (Jagals & Van der Walt 2016) as a SNA tool for social network analysis will also be considered. This software package provides the affordance of the analysis and visualisation of collaborative networks, and might provide us with information on collaborative learning in this project. Interviews, open-ended questionnaires' responses and observations (field notes and video recordings) will be transcribed. Saldaña's (2009) coding technique will be used to identify codes, categories and emerging meaningful themes from the data. Data triangulation will provide a 'rich description' (Geertz, 1973), and CHAT as lens will assist to identify tensions (factors influencing the PoP in the teaching of contextualised mathematics lessons). This will assist the researchers to distil design principles for future interventions.

Validity

McMillan & Schumacher (2001, p. 408) recommend different strategies to increase the reliability of a qualitative research design. These strategies include being in the field over a long period of time; taking the language of the participant into consideration; more than one researcher participating in the research; participants checking the data and interpretation thereof & collecting data at different

phases of the project. Furthermore, these authors also recommend the following strategies to be used to ensure reliability in qualitative data analysis: credibility, applicability, consistency and neutrality.

FINDINGS

The findings will enhance our understanding of how such interventions are structured to ensure the development of teachers as self-directed teachers.

CONCLUSION AND RECOMMENDATIONS

The most important group to benefit from this research, would be South African learners. The implementation of a contextualised approach in the mathematics classroom would make mathematics more relevant and accessible for South African learners. This project will contribute to empowering teachers to facilitate the epistemological border crossing from theory to practice through the envisaged development of a PoP using MSK. Another outcome would be mathematics teachers' metacognitive and professional development.

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SCIENCE EDUCATION PAPERS

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PERFORMANCE IN CHEMISTRY: A COMPARATIVE CASE STUDY OF PUBLIC AND PRIVATE SECONDARY SCHOOLS

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ABSTRACT: Formal education is the source of economic development for the common population of a country. After being at a disadvantage concerning quality education, deprived community members focus on improving the life style of their children by introducing them to quality secondary school education. The previously disadvantaged middle class population of South Africa (pre 1994 era) has developed a trend of sending children to privately-owned secondary schools. Being secondary school teachers from a government-owned public school in South Africa, the researchers aimed to understand parents' preference for sending their children to private schools. Parents indicated that a private school imparts better education in terms of teaching-learning outcomes due to the abundance of resources in private schools. This quantitative study explored the impact of resources in chemistry teaching learning outcome and hence attempted to determine the viability of sending children to privately-owned secondary schools in favour of government-owned, public schools. The findings reveal no significant difference in the performance when comparing public and private secondary Science results. A crowded classroom's, lack of educational software, internet access for learning and teaching materials, exert a minor influence on teaching-learning outcomes in Science. The teacher's knowledge and practical skills to assist with experiments proved to be very influential when it comes to academic achievement in science.

Keywords: Lecture method of teaching; public schools; effect of resources

INTRODUCTION

The present social context suggests that our academic success starts with the achievement of a Grade 12 certificate. This examination is commonly known as the matric examination by the South African population. Officially it is known as National Senior Certificate Examination (NSCE). Twenty four years of a post-apartheid education has shown the dire need to prioritise children's education. This awareness has been perceived differently by community members, since many of them do not have faith in a government-funded public school education system.

The middle class population in South Africa is influenced by its previously disadvantaged history (pre 1994 era) and community and has developed a trend of sending children to privately-owned secondary schools. Maile (2004) observes middle class families from the previously disadvantaged community prefer private or previously categorised Model C schools. In many cases we observed that if a child was doing better in the senior-phase (Grade 8 -9), the student was sent to a nearby private school for the Further Education and Training (FET) for Grade 10-12.

The researchers decided to empirically determine and compare the performances of a private school to its public counterpart when all other variables remained constant. The generic choice was Physical Science. Furthermore, the study was directed at the achievement of Physical Science teaching and learning outcomes in the schools under observation.

The researchers focused on the Grade 11 Physical Science paper two for the purpose of investigation of students' performance in selected state controlled tests. This paper covered the Chemistry content as prescribed by the CAPS document of South Africa, which includes chemical bonding and related aspects, water chemistry, gas laws, stoichiometric studies, chemical kinetics, acid base reactions, oxidation-reduction reactions and lithosphere. This study focused on the attainment of the overall teaching-learning outcomes in Chemistry as a subject, hence no recording was made about the content

covered under each individual question to correlate students' performance with a specific content. This study assisted us to determine the impact of resources in Chemistry teaching learning outcomes and hence, sought to probe the viability of sending children to a privately-owned secondary school.

AIM

The primary aim of this study was to identify the dominating factor that influenced the teaching-learning outcomes of chemistry namely, resources and teaching methods. The secondary aim of the study was to have a reality check on the teaching-learning outcome of private schools in general and to indicate the effectiveness of the private schooling system.

OBJECTIVE

The objective of the study was to identify the dominant, contributing factor focusing on the teaching methods used for teaching-learning processes of Chemistry and resources available to carry out the practical experiments. The shortage of resources served as indication to the policymakers that reform is required in our public school system for improving chemistry teaching-learning processes in Physical Science in general.

THEORETICAL FRAMEWORK

It was suggested that community members who had economical resources to join a paid school had a better opportunity to receive quality education (Reddy, 2006). It was also maintained that 80% of schools believed lack of quality educational resources hinders students; learning (Savasci & Tomul, 2013). Scholars also reported that socioeconomic factors remain at the forefront in contributing to students' performance (Hanushek & Luque, 2003). When attempting to identify the dominating effect of resources in teaching-learning outcomes, it was feasible to compare the performances of students belonging to two different categories viz. resourceful and resource crunched schools where both groups were taught in similar fashion by using similar pedagogic practices. Empirical evidence suggests that crowded classroom, lack of educational software, lack of internet access for learning and lack of teaching materials had the least impact on teaching-learning outcomes for a large group of Grade 7 learners (Savasci & Tomul, 2013).

If the socioeconomic factor determines the students' performance then it can be asserted that students from a private school would perform significantly better than their peers from a public school in a given community where attending a public school entails a lack of resources. Through this study an attempt was made to empirically identify the impact of resources on Chemistry teaching-learning outcomes on students' academic performance in a single community in rural South Africa where students were taught via teacher-centered note-and-question-paper solving methods (Chowdhury, 2015).

CONTEXT OF THE STUDY

It was predetermined by the researcher that before selecting the sample for this study of students' performance the size of both classrooms and socio cultural background of all the students' would be kept constant at its maximum possible probability. After careful observations, two schools in the Nkomazi municipal area of Mpumalanga province were conveniently selected for this study. One of the schools was a private school at a nearby town Malelane and the other school was a no-fee public school situated in a village called Middel plaas. Both the places were well connected by road transport. There was a common denominator between the students of both the private and the public schools; they shared the same sociocultural background. All students of these schools belonged to the previously disadvantaged community of pre-1994 era. They spoke the same language at home (SiSwati), shared the same social values and faith and resided in the same municipal area. The only difference which existed among the students was the economical affluence and affordability in paying secondary school fees. The students coming from financially secure families attended the private school, and the students having lesser economic freedom attended the no-fee public school. In short, students having resources attended a resourceful private school. On the other hand the resource-

strained poor students attended the resource-scarce public school. The private school was equipped to teach learners using technology, the library and laboratory. The public school did not have any laboratory, working library or electronic devices to support teaching-learning activities. It was obvious that the private school had better resources when compared to its public school counterpart. The author argued, if the resources were supposed to be a strong determining factor towards a better learning outcome then, the Chemistry students from the private school would outperform the students from the public school. It had already been argued that, students from wealthy families perform better due to availability of resources (Reddy, 2006).

RESEARCH QUESTION

The following research question was formed for the purpose of this study:

How do students from affluent and deprived schools differ when comparing the final academic results of the chemistry examination?

METHODOLOGY

A post study controlled test method was used for this study. In this quantitative method of study a state controlled test which was administered by the Mpumalanga Education Department, was considered as a standard teaching-learning output measuring tool for the subject physical science. The test was held at the end of the academic year of 2015. Performances of students' were collected for the study purposes and analysed. The number of students passed in each question for the selected schools were identified and used for statistical analysis.

Sample of the study

Grade 11 Chemistry classes from the two selected schools were considered as samples. The samples were collected so that both the sample may contain an almost equal number of members. Bearing in mind practicality, it was found to be very difficult to involve two similar class groups from the same population simultaneously. The selected sample groups were quite close to each other. There were 40 students in the public school (N_1) and 49 students in the private school (N_2). So the sample size was considered to be adequate to serve as data. Teachers in both schools were using traditional teacher-centred methods to teach (Kazeni & Onwu, 2013; Chowdhury, 2015; Markic et al., 2016). This allowed the researcher to agree about the following facts.

Teachers from both the schools used similar pedagogical methods to teach in their classes. It was also informed that students from the private school observed at least four different practical experiments (using video graphs of practical experiments and live by the subject teacher). On the other hand, students from public school could observe only two experiments demonstrated by the teacher. Students from the participating public school were not allowed to perform any practical experiment on their own. Hands-on practical experiments were also not done by the students from the private school. Our team argued, that since there was no difference between the two groups in terms of the class size, the performance analysis of both the sample groups would assist us to understand the effect of resources on chemistry teaching outcomes. The intention was to gather some empirical evidence about teaching-learning out come in chemistry using these two schools.

Testing instrument

The final examination paper for Grade 11 students' studying, Physical Science Paper 2 for the year 2015 was considered for the purpose of this study. The Department of Basic Education (DobE), Mpumalanga province, prepared the question paper. Moreover, it was considered standard, valid, and reliable for measuring teaching-learning outcomes in Chemistry for both the sample groups. The said question paper had ten questions. The test was administered by the Mpumalanga Department of Basic Education. We collected the anonymous papers of all 89 students for both the private school and the public school. The performance trend of individual students remained anonymous on the record sheet.

This question paper had ten questions and was divided as follows: Question 1: Grade 11 Chemistry contents of a year; Questions 2 and 3: Bonding and properties; Question 4: Gas laws were covered; Questions 5 and 6: Stoichiometry included a question on empirical formula; Question 7: Exothermic and endothermic equations; Questions 8 and 9: Acid base reaction and redox reactions; and Question 10: Metallurgy.

DATA COLLECTION

Final examination scores for Grade 11 students' studying, Physical Science Paper 2 for the year 2015 were considered for the purpose of this study. Data were collected after the test was implemented, moderated and announced to the students. Primary raw data were collected in terms of pass or fail in a question instead of collecting actual scores of the students in a given question. The data were collected from both the schools, and these scores are tabulated in Table 1.

Table 1: Number of students passed in each question from two selected schools and % pass

Q No	1	2	3	4	5	6	7	8	9	10	N total
N ₁ pass	29	16	10	7	6	5	25	4	0	10	40
% pass	72.5	40	25	17.5	15	12.5	62.5	10	0	25	
N ₂ pass	41	21	17	12	7	13	14	11	11	17	49
% pass	83.7	42.9	34.7	24.5	14.3	26.5	28.6	22.4	22.4	34.7	

The scores were then converted into a bar graph (Figure 1) to show the normal statistical trend between the two sets of sample groups.

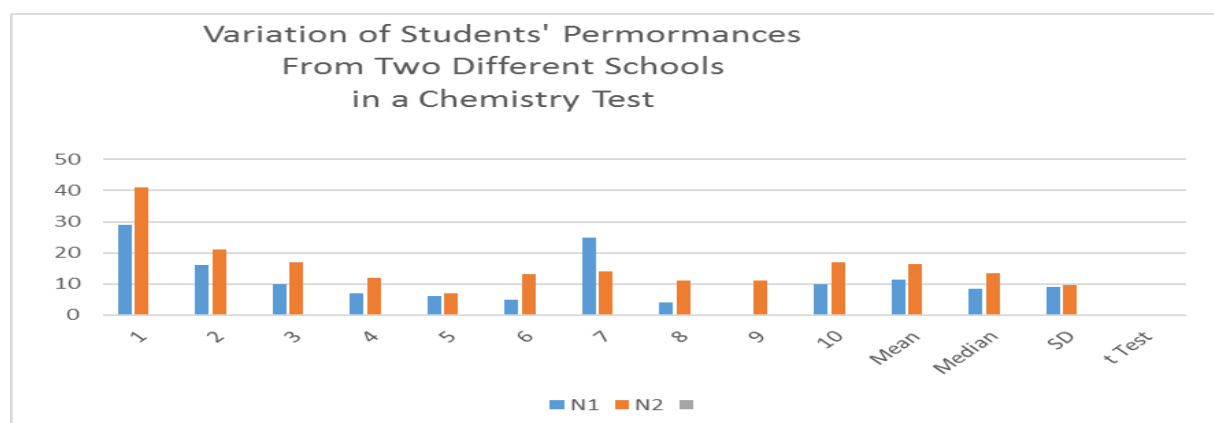


Figure 1: Bar graph indicating a variation of learners' performance

Number of Students passing in each question from Private school (Red) and Public School (Blue) showing Mean, Median, Mode and Standard Deviation for the numbers of students passed from each of the schools. The prominence of the red was visibly high in the graph (Figure-1).

The number of students who passed in each question in the public school are indicated in blue (N₁ = 49). The number of students who passed in each question from the private school is indicated in red (N₂ = 40). The prominence of the red was visibly high in the graph (Figure-1). Important statistical data were tabulated in Table 2.

Table 2: Number of students passed in each question

Questions	N1	N2
1	29	41
2	16	21
3	10	17
4	7	12
5	6	7
6	5	13
7	25	14
8	4	11
9	0	11
10	10	17
Mean	11,2	16,4
Median	8,5	13,5
SD	8,908423	9,489175

Two sets of data, having an inclusive population of 89, had degrees of freedom 87. A value of significance 0.05 that is equivalent to 5% was assigned to the data set. While co-relating the scores of both the schools a t-Test score-valuing 0.2339 was obtained (Table 3).

Table 3: Central tendencies

Statistical results for number of Students passed per school	Public School	Private School	t-Test value
Mean	11.2	16.4	
Median	8.5	13.5	0.2339
Standard Deviation	8.91	9.48	

ANALYSIS OF DATA

The following observations were made from the Table 1 of the collected data. A common trend was observed in students' performances. Students from both the private and the public schools were performing well in question number one. The number of students who passed in the private school was 11% higher than the number of students passed in the question one from the public school. On the other hand, students from both of the schools performed poorly in remaining questions, question number two to question number ten. Question number one consisted of a combination of ten multiple-choice questions and learners were required to find the correct answer from a given set of five answers. It was argued that students' ability to recall and write assisted them to perform well in the question number one. Another factor presumed to assist the students to score well was guess work to answer. It was also observed that less than 40% of the students were passing almost in each of the other questions (both schools). The exceptions were question number two (bonding) where students from both schools showed more than a 40% pass rate. Question number seven (Exothermic and endothermic reactions) for the public school where students registered, more than 60% pass. In other questions students from both private and public schools were performing poorly. We observed that public school students performed better in some content areas than their private school counterpart. Resources were not necessarily helping private school students' to perform better. While observing the overall performances the researchers were able to draw a conclusion that both the private school and the public school students performed poorly in the observed Chemistry test.

The central tendency (Table 3) values for the private school showed a higher trend when compared with the public schools' performance. The findings reveal that more students from the private school passed. Studying the values of standard deviations for both the school, it was observed that the scores of the private school show a more balanced distribution in comparison with those of the public school. The means performance variations were predominant amongst private school students'. performance of students from private school were not uniform; some were doing very well and on the other hand some were doing very poorly causing the higher gaps in central tendency, whereas performances of students' from the public school were more centralised and less spread. This observation helped us to conclude that resources did not exclusively assist in performance enhancement. We might conclusively say that teaching-learning outcomes for both the private school and the public school were very poor depending on the students' performance in the test administered by the department of education. We were yet not in a position to determine the relative contribution made by these schools in their chemistry teaching-learning outcome.

It was known from the tabulated t-test chart that, for degrees of freedom 87 the t-test tabulated value should be between 1,990 and 1,987 (t-Test, 2017). From the collected data obtained 0,234 was calculated as t-test value (Table 3). If the tabulated t-test value for a given degrees of freedom is greater than the calculated t-test value then statistically it is not possible to distinguish between the two sets of data. It means that there was no significant difference between the two score sets of data collected after administering the chemistry tests to the students. Therefore, the researchers might safely say that our null hypothesis is accepted in light of the given set of data.

CONCLUSION

In conclusion, there was no significant difference in the performance of the students from the sampled schools. Hence, the achievement in the chemistry-learning outcomes is the same for both the private and the public schools taken into consideration. This contradicts the theory that suggests economical resources of necessity provide better opportunities in educational environments (Reddy, 2006). On the other hand it strengthens the findings that a crowded classroom's lack of educational software, lack of internet access for learning and lack of teaching materials, exert a minor influence on achievement of teaching-learning outcomes (Savasci & Tomul, 2013). Although this study was limited to a small sample in a municipal area, it had the advantage of studying the learners from the same community in different learning environments. Resources might help in performance enhancement, but it is not the necessary sufficient condition for improving chemistry teaching-learning outcomes. It has been reported that learning outcomes are mostly influenced by the teachers' classroom practices (Wenglinsky, 2002).

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PROJECT-BASED LEARNING AND CLASSROOM ACTION RESEARCH IN THE SCIENCE CLASSROOM

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ABSTRACT: In this paper I reflect on the experiences of Life- and Natural Sciences teachers in the Northern Cape who engaged in classroom action research (CAR). The activity which was the focus of the teachers' action research was learners' engagement in project-based learning, namely an ethnobotanical survey. During a short learning programme (SLP) of the NWU in June 2017, Natural Sciences teachers were shown how learners could engage in ethnobotanical surveys. Part of the portfolio that teachers had to submit after the SLP, was a reflection on such classroom action research. These portfolios were analysed, and several emerging themes were identified from the data. Three such themes are highlighted in this paper. The findings indicate that such project-based learning holds affordances such as the realization of affective outcomes in science education. It also assists science teachers to become more critical reflective practitioners, and also enhances self-directed learning. One of the recommendations of this paper, is that CAR should be promoted in both pre-service and in-service teacher education programmes.

Keywords: Classroom action research; project-based learning; ethnobotanical surveys; teacher professional development; prolepsis.

INTRODUCTION

In 2016 the North-West University started to offer a short learning programme for Natural Sciences teachers, with the primary aim to assist them to better contextualize curriculum topics through the infusion of indigenous knowledge. Although the Curriculum- and Assessment Policy Statement (CAPS) advocate for the inclusion of indigenous knowledge, it does not provide teachers with much guidelines on how to do such epistemological border-crossing in the science classroom. Most teachers were not trained to infuse indigenous knowledge into CAPS themes, as several researchers have pointed out (Mothwa, 2011; Jautse, Thambe, & de Beer, 2016; Cronje, de Beer, & Ankiewicz, 2015; de Beer & Petersen, 2016). The SLP therefore focuses on how indigenous knowledge could be dealt with in the science classroom, in a way that will be aligned to the tenets of science. Cronje *et al.* (2015) shows that indigenous knowledge share several similar tenets with the natural sciences. Among others, both indigenous knowledge and natural sciences are characterized by its empirical, tentative and inferential nature. There are of course also differences. Science is predictable, whereas indigenous knowledge often has a metaphysical component as well. Furthermore, indigenous knowledge is holistic, whereas natural science follows a reductionist approach (Cronje *et al.*, 2015, p. 324).

Odora Hoppers (2004) refers to the marginalization of indigenous knowledge in the classroom as 'knowledge apartheid'. Where teachers do refer to indigenous knowledge, it is often done through an example or two, but such engagement lacks the rigor of science embedded within the syntactical nature of the subject, and without cognizance of the tenets and nature of science. De Beer and Whitlock (2009) uses the metaphor of dead biotic tissue preserved in bottles with formaldehyde solution, in describing how indigenous knowledge is often dealt with in the science classroom. During the short learning programme, teachers are shown how learners can engage with indigenous knowledge through inquiry learning. For example, teachers engage hands-on during the programme in an adapted Kirby Bauer technique, to test whether *mutshi* (medicinal) plants have antimicrobial activity. This takes teachers (and the learners) on a journey of inquiry learning, where they have to

formulate hypotheses, design experiments, make careful observations, and communicate their findings. The Kirby Bauer laboratory protocol is a simple way of determining the susceptibility of a micro-organism to an antimicrobial substance (present in the medicinal plant). Microbe-seeded agar plates are used to test for antimicrobial activity (Mitchell & Cater, 2000; de Beer & Whitlock, 2009). By creating such inquiry-based learning opportunities, learners will be able to see how indigenous knowledge could have its place in the natural science.

However, NWU researchers came to realise that the short learning programme had limited success. Although teachers expressed their enthusiasm to implement indigenous knowledge in their teaching after the SLP, very little transfer actually took place in the classroom after the intervention (White & de Beer, 2017; Jacobs, 2018). Classroom observations, and evidence provided in teachers' portfolios, suggested that many teachers reverted back to transmission-mode (chalk-and-talk) teaching and learning, and lip-service was paid to indigenous knowledge. This is unfortunate, as transfer into the classroom is "where the rubber hits the road", and should be the yard stick to measure the success of teacher professional development programmes. For this reason, researchers distilled (in true design-based research tradition) design principles for the SLP. These are dealt with in another publication (de Beer & Kriek, n.d.). Such design principles include taking *real* teacher needs into consideration when planning such SLP's, emphasizing inquiry learning, and building these programmes on strong theoretical frameworks. One design principle which is the focus of this paper, is to assist teachers in their reflective practices. Research indicates that reflection is essential for teacher professional development. Teachers' reflective abilities can be enhanced by engaging them in classroom action research.

Teachers who participated in a later SLP in the Northern Cape (June 2017) were therefore exposed to a revised short learning programme, in order to ensure more transfer into the science classroom. This second cycle of SLP offerings, introduced teachers to classroom action research that investigated the affordances of project-based learning in the science classroom. One of the activities that teachers engaged with during the SLP, was the ethnobotanical survey that De Beer and Van Wyk (2011) devised. The Northern Cape (Hantam region) was once the home of many Khoi-San, and many of the teachers in the Namaqua district are of Khoi-San descent. In this generally socio- economically poor region, many people still use medicines derived from plants growing in the environment. De Beer and Van Wyk (2011) described a procedure whereby learners can engage in preparing herbarium voucher specimens of plants in the region, developing a questionnaire, doing a survey, and then present their results by providing indices such as the Ethnobotanical Knowledge Index (EKI) and Species Popularity Index (SPI). Teachers could plan such project-based learning by means of classroom action research. In this paper, I present the data collected after teachers engaged in such classroom action research.

PROJECT-BASED LEARNING AND CLASSROOM ACTION RESEARCH

Teachers were requested to engage learners in project-based learning after the short learning programme, as described in the previous paragraph. Furthermore, teachers were required to do classroom action research (CAR), and to reflect on this CAR in their portfolios.

Project-based learning: Engaging in ethnobotanical surveys. Krajcik and Shin (2016, p. 276) state that project-based learning environments have six key characteristics, namely:

- Project-based learning should start with a driving question, or a problem to be solved.
- The teacher should clearly determine what learning goals should be achieved.
- Learners should explore the driving question by participating in scientific practices.
- Learners should engage in collaborative activities to find solutions to the driving question.
- Learners are scaffolded with learning technologies.
- Learners create a set of tangible products that address the driving question.

For the ethnobotanical surveys, a suitable driving question could be: 'Indigenous knowledge is an oral tradition. If knowledgeable elders die, this knowledge is often lost for future generations. How can we therefore preserve the rich ethnobotanical knowledge of the Namaqua district?'

Classroom Action Research (CAR)

Mettetal (2002) describes classroom action research as a midpoint between teacher reflection at the one end, and traditional educational research at the other. CAR is more data-based and systematic than reflection, but also less formal and controlled than educational research (Gravett & de Beer, 2015). During the SLP in the Northern Cape teachers were shown how such CAR should follow steps such as (a) identifying a research problem [and formulating a research question], (b) planning an intervention [in this case, project-based learning], (c) acting and collecting data [evidence, e.g. in the form of learners' portfolios or projects], (d) analyzing this data, and (e) evaluating the intervention, and deciding on how this would inform teaching practice in future (Gravett & de Beer, 2015). Teachers mostly decided to focus their CAR on ethnobotanical surveys, although a few teachers did choose other teaching interventions.

Research methods

This paper reflects on design-based research, during which Natural Sciences teachers from the Northern Cape (Namaqua district) engaged in classroom action research. Data were collected from 37 teachers who participated in the intervention. Individual interviews were conducted with a few (n = 5) teachers, and convenience sampling was utilized. These interviews were transcribed and analysed. All submitted portfolios, which included teachers' reflections on CAR, were analysed. I utilized Saldaña's (2009) coding technique. Codes were identified and grouped into categories, and from these categories, emerging themes were identified. Construct validity of the interview protocol was ensured by asking a panel of experts (that included the university's Statistical Consultation Services) to peruse the protocol.

FINDINGS

Unlike previous cycles of the short learning programme, e.g. the interventions in Limpopo Province in 2016 (Jacobs, 2018; White & de Beer, 2017), where little transfer took place in the classroom after the SLP, it was encouraging to see that there was a genuine attempt by many Northern Cape teachers to exchange transmission-mode teaching for inquiry learning, and to attempt the CAR with enthusiasm and dedication. A number of themes were distilled from the data, of which three are discussed in this paper.

Theme 1: The affective domain was center-staged in both learners' project-based learning, and in teachers' classroom action research

Given the difficulty of measuring conceptual change, and the complexity of showing a relationship between cognitive gains and a specific intervention, we advised teachers during the SLP to rather focus on learners' affective gains during their classroom action research. For this reason, the majority of teachers formulated research questions such as "*What is the effect of learners' engagement in an ethnobotanical survey on their attitudes and interest in Life Sciences?*" Teachers obtained data to answer their research questions through the application of questionnaires, studying artefacts (learners' projects), and arranging focus group interviews with the learners. Most of the teachers reported that there was a renewed 'energy' in the classroom, and that learners were very interested in and inspired by the project-based learning.

This theme can best be illustrated through a vignette. A teacher in Calvinia engaged her Grade 10 learners in such ethnobotanical surveys. One of the learners, Henrico Thys, got so interested in the plants of the Hantam area, which he went to the Calvinia library, to ask for books on the plants of the region. He was, amongst others, given a thesis on the ethnobotany of the Agter-Hantam by De Beer (2012). In this work, photographs are shown of novice botanists in the area, who were consulted by

the researchers. In the book, Henrico saw the photograph of his uncle, Martiens Thys, and this inspired the boy to consider a career in ethnobotany, because of the “knowledge in the blood”. Both the portfolios, and the interviews conducted with teachers, indicated that affective outcomes were achieved, and that the learners enjoyed the learning experience. Several teachers also reflected on how this will encourage them to engage more often in such CAR. One of the teachers commented during the interview that *“I did the action research with a very difficult class, and it was wonderful for me to see how the learners were all engaged, and how they got excited about the project. It gave me joy to witness the learners’ enthusiasm”*.

Theme 2: Classroom action research assists science teachers to become more critical reflective practitioners

During previous cycles in this design-based research (e.g. in Limpopo, North-West Province and Gauteng, on which authors such as De Villiers *et al.*, 2016; De Beer and Petersen, 2016; and White and De Beer, 2017, reported), teachers provided very superficial reflections in their portfolios. The researchers came to realise that, given the systemic pressures on teachers (e.g. the full curriculum) many teachers do not make time to reflect on their teaching.



Figure 1: An example of artefacts from a Teachers' portfolio, reflecting on the ethnobotanical survey

The batch of Northern-Cape portfolios included far more nuanced reflections. One of the reasons for this, was the focus on CAR. One of the teachers commented as follows: “At first I was terrified by the thought that I should do research. However, I had to do it, since I wanted to submit my portfolio. The classroom action research provided me with new insights into my own teaching. I saw how excited learners became when they did the survey, and gained knowledge on the medicinal plants in the Calvinia environment. And this was so gratifying, that I am dedicated to more often engage my learners in such activities”. Another teacher had the following to say in her portfolio: “When my learners presented their projects to the rest of the class, I could not believe that these were the same kids that were so disinterested in the work a month ago. There was an electrifying energy in the air, and I could sense the pride that learners took in their projects. This is of course the fodder that teachers live on, and I am definitely going to give my learners a similar project next year”.

Theme 3: Classroom action research might enhance teachers' self-directed learning

Knowles (1975, p. 19), generally considered as the progenitor of self-directed learning, described it as “a process by which individuals take the initiative, with or without the assistance of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating outcomes”. Teachers mentioned in their portfolios that they felt slightly overwhelmed by having to engage in classroom action research. One of the teachers stated that “I was anxious at first, but upon completion of the CAR I enjoyed a wonderful sense of accomplishment. I learnt so much!”

Prolepsis is a teaching technique that Van Lier (2004, p. 153) describes as “assuming that students know more than they actually do”. In other words, the learning task is conceptualized in such a way that it poses a challenge to the learner. Meerkotter (1980), in a classic study, has shown that

learning tasks that pose a challenge, and expect behavior such as analysis, synthesis and evaluation, more often lead to creative learner outputs (compared to learning tasks that merely depend on regurgitation). The portfolio requirement that teachers should engage in CAR could therefore be seen as prolepsis, and teachers were challenged in their professional learning, across the zone of proximal teacher development (Warford, 2011). Several of the teachers rose to the occasion. Most of the CAR projects focused on implementing strategies to address affective outcomes. Most of the projects/ interventions focused on ethnobotanical surveys, but there were also a few notable exceptions, for example a project where learners isolated DNA from bananas, and a water quality project, where Foldscope microscopes were utilized by the learners. From teachers' reflections, it became clear that they developed self-directed learning skills in the process. Marlize (a teacher in Calvinia), realized that she was not very knowledgeable on the indigenous plants of the region. She chose however to give her learners an ethnobotanical survey project, and set a learning goal for herself: becoming more acquainted with the local flora. She then identified a knowledgeable person who could assist her in her learning journey: Francois, an attorney who lived on one of the nearby farms, and who happened to be a keen amateur botanist. Francois assisted her and the learners, in identifying less well-known plant species. Marlize also consulted library books and the internet, on conducting classroom action research. She submitted a very good CAR project, as part of her portfolio.

CONCLUSION AND RECOMMENDATIONS

The theoretical framework that underpins these short learning programmes for teachers, is social-constructivism. In the design of these SLP's, the developers take cognizance of Warford's (2011) take on the well-known Vygotsky construct of the zone of proximal development. Warford speaks of the 'zone of proximal *teacher* development' (ZPTD). In scaffolding teacher professional development across the ZPTD, the technique of prolepsis seems helpful. This paper focused on the affordances of teachers engaging in classroom action research. The data shows that CAR assists in the development of teachers' reflection skills, and that it could also enhance self-directed learning.

I conclude with two recommendations:

- (a) Classroom action research should receive more attention in both pre-service and in-service teacher education. I concur with John Slaughter, as quoted in Chmielewski and Stapleton (2009, p. 53), who said that "research is to teaching what sin is to confession. If you don't participate in the former, you have very little to say in the latter".
- (b) Such teacher professional development is best achieved within well-functioning communities of practice. Teachers engaging in CAR needs 'critical friends' with whom they can soundboard ideas.

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DEVELOPING DESIGN PRINCIPLES FOR AN INDIGENOUS KNOWLEDGE INTERVENTION FOR LIFE SCIENCES TEACHERS BASED ON SOCIO-CONSTRUCTIVIST PEDAGOGICAL STRATEGIES

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ABSTRACT: Despite the increasing focus on classroom practices characterized by socio-constructivist pedagogical strategies and inquiry learning, behavioristic classroom practices are still dominant in Life Sciences classrooms. Apart from the fact that many Life Sciences teachers struggle to replace transmission-mode teaching with inquiry learning, they also face a second challenge. The historic events in 1994 which brought about democracy in South Africa also resulted in a reform in educational policies and content – including an increased focus on indigenous knowledge. Thus far the Department of Education has failed to provide sufficient teacher training with regards to socio-constructivist pedagogical strategies that could scaffold the inclusion of indigenous knowledge in Life Sciences teaching. Studies show that both socio-constructivist pedagogical strategies and the inclusion of indigenous knowledge contribute to the development of learners' self-directedness in learning. This paper views the development of design principles for an indigenous knowledge intervention for Life Sciences teachers, based on socio-constructivist pedagogical strategies. Participants were chosen randomly from Life Sciences teachers who voluntarily attended the short courses. A design-based research design was used (this paper reports on the first cycle), and data were collected by making use of questionnaires, observations and interviews. This paper captures the feedback of the participants who took part in this study. Nine (9) design principles were distilled from the data.

Keywords: Problem-based learning (PBL); cooperative learning (CL); indigenous knowledge (IK); self-directed learning (SDL); pedagogical content knowledge (PCK); socio-constructivist pedagogical strategies

INTRODUCTION AND PROBLEM STATEMENT

Despite the need for education based on socio-constructivist learning principles, many teachers still use behaviorist learning theories (Garrett, 2008, p. 34; de Beer & Mentz, 2017). Authors such as Haefner et al. (2006, p. 207-208), Mansour (2009, p. 289) and Milner et al. (2010, p. 154-157) emphasize the importance of basing educational activities in Life Sciences classrooms on socio-constructivism aimed at the promotion of self-directed learning. Socio-constructivist pedagogical strategies such as experimentation, field trips, the use of problem-based learning and cooperative learning provides the opportunity for learners to construct their own learning and to develop various skills (Schreiber & Valle, 2013, p. 398-401) in order to develop as self-directed learners who take responsibility for their own learning (Killen, 2003:178). A lack of time and the necessary pedagogical content knowledge does, however lead to Life Sciences teachers in South Africa shying away from implementing socio-constructivist pedagogical strategies (Froneman et al., 2000, p. 195-196; Sanders & Nduna, 2006, p. 19; Petersen & De Beer, 2012, p. 2; Botha, 2012, p. 2).

This study was aimed at developing design principles for an indigenous knowledge intervention for Life Sciences teachers based on socio-constructivist pedagogical strategies. Such an intervention should be aimed at empowering Life Sciences teachers to teach indigenous knowledge and make use of socio-constructivist pedagogical strategies in their teaching, and in the process, develop self-directed learners.

The historic events in 1994 leading to democracy in South Africa, also led a reform in educational policies, content and methods (Khupe, 2014, p. iii). Even though the integration of indigenous knowledge into the content of the Life Sciences curriculum is required according to policy documents, several factors hinder this integration (Cronjé, 2015, p. 233-234). Indigenous knowledge seems to provide an exceptional approach to the national curriculum in South Africa but is marginalized due to a still prominent Eurocentric view rendering it a pseudoscience or unscientific (de Beer, 2015, p. 1).

Thus, a need exists to equip Life Sciences teachers with the necessary pedagogical content knowledge (PCK) – according to the concept of Shulman (1986, p. 9-10)--to address the abovementioned issues, and this far the Department of Education did not provide teachers the appropriate training in this regard (Mothwa, 2011, p. 4; de Beer & Mentz, 2017).

THEORETICAL AND CONCEPTUAL FRAMEWORKS

This study was based on socio-constructivism as theoretical framework. According to the socio-constructivist theory of Vygotsky (1978), learning can be seen as the active discovery and construction of knowledge which takes place by authentic socio-cultural relationships, cooperative learning, problem solving and shared meaning within the zone of proximal development (Kivunja, 2014, p. 83). This theory emphasizes meaningful learning as a social and cultural process (McMahon, 1997). This study focused on the professional development and scaffolding (mediation) of teachers across the zone of proximal development (Vygotsky, 1978) with regards to the successful integration of indigenous knowledge and the use of socio-constructivist pedagogical strategies aimed at the development of self-directed learners.

IK is fluid knowledge, skills and attitudes particular to a specific indigenous group of people. It is developed over centuries and continues to develop by interactions of people with nature. It is conveyed (usually verbally) from generation to generation (de Beer & Mentz, 2017). This knowledge, skills and attitudes are cultural and is mainly used for survival and to enhance the quality of the people belonging to a specific group of people (Le Grange, 2004; Naidoo, 2010; Mothwa, 2011; Zinyeka, 2013; Khupe, 2014).

According to Hardy-Vallee and Payette (2008) cognition is a holistic process rather than the traditional view of the brain as the only place where cognition takes place. These authors view cognition as being embodied (it cannot be separated from action and perception), situated (influenced by prior knowledge, background and environment) and distributed (influenced by social interactions). Therefore, the teaching-learning approach in classrooms and the content taught influences learners' perceptions of their learning – IK (prior knowledge) and the use of socio-constructivist pedagogical strategies should thus contribute to meaningful learning. Furthermore, Jegede and Aikenhead (1999) argue that learners often experience the world they live in and school science as two different cultures and that teachers act as cultural brokers who ensure that these two cultures exist in harmony in order to ease the crossing of cultural borders. If this is not achieved, learners may be alienated from one of these cultures (Jegede & Aikenhead, 1999). To prevent this, Life Sciences teachers (especially in the South African context) need to use appropriate pedagogical strategies to facilitate the crossing of borders. The short course described in this study was planned keeping such embodied, situated and distributed cognition in mind.

Socio-constructivist pedagogical strategies refer to teaching-learning strategies which encourage learners to use active techniques to create knowledge, based on prior knowledge, and reflect on their learning within a social environment (Ruey, 2010). This may include strategies such as experimentation, field trips, the use of problem-based learning and cooperative learning to mediate learning (Schreiber & Valle, 2013, p. 398-401). Teachers should direct their educational activities

towards developing self-directed learners and authors such as Killen (2003, p. 178) argues that socio-constructivist pedagogical strategies may be used to develop learners' self-directedness in learning. Knowles (1975, p. 19) defines SDL as a process during which individuals identify and formulate their own learning needs and learning goals, they identify their own learning resources, they make decisions about and implement appropriate learning strategies and evaluate the outcomes of their learning. This may be done with or without support from others.

METHODOLOGY

Approach and paradigm

This paper reports on a study aimed at developing design principles for an indigenous knowledge intervention based on socio-constructivist pedagogical strategies. A design-based research design was used for this research, and this paper reports on the design principles developed after the first cycle of the research. Participating teachers' professional development as well as their perceptions of their own professional development served to provide a deeper understanding of design principles to inform future indigenous knowledge interventions based on socio-constructivist pedagogical strategies.

The intervention

The data for this study were collected during two three-day short courses for Life Sciences teachers. One took place at the Turfloop campus of the University of Limpopo in Polokwane (27-29 June 2016), and the second at the NWU in Potchefstroom (18-20 July 2016). This study reports on the first cycle of interventions in the project.

During these IK interventions, teachers were introduced to ways in which IK can be incorporated in the Life Sciences curriculum by making use of the processes of science. These interventions consisted of laboratory experiments (anti-microbial tests on medicinal plants, using the Kirby-Bauer technique), as well as PBL and CL activities. There was a strong emphasis on providing teachers with a more nuanced understanding of the nature of science, the nature of IK and the principles underpinning SDL (including the link between PBL and SDL) (De Villiers *et al.*, 2016).

Teachers were required to submit a portfolio after attending the short course. These portfolios were not used as part as the data for this study, but observations were made on the issues regarding the submission of the portfolios, and these were considered during the development of the design principles.

Data collection

Data were gathered by making use of standardized as well as self-constructed questionnaires, classroom observations and individual interviews. Two types of questionnaires were used – the views-on-the-nature-of-indigenous-knowledge (VNOIK) questionnaire (Cronjé, 2005) was administered before and after the interventions and was aimed at gathering data on the participating teachers' views on the nature of indigenous knowledge. The second questionnaire, a generic questionnaire, was completed by teachers after the interventions and was aimed at determining the thoughts of the teachers on different elements of the interventions as well as their attitudes towards socio-constructivist pedagogical strategies and IK. Eight teachers were interviewed during the interventions and three teachers were selected (based on availability and willingness) for classroom observation and further interviews. The interviews were directed towards gathering data on the views of teachers on the changes brought about in their professional development, their skills and attitudes as a result of the interventions, as well as the factors that promote and prevent the use of socio-constructivist pedagogical strategies and the integration of IK.

Sampling

A convenience sampling method was used – only Life Sciences teachers who attended the interventions participated in this study. All the teachers who attended the intervention (62 at the UL-intervention and 13 at the NWU-intervention) were asked to complete the VNOIK questionnaire before and after the course and the generic questionnaire after the short course. Individual interviews were conducted with eight randomly selected teachers who were willing to participate during the interventions. About two months after the Limpopo short course, we visited three of the teachers who attended the short course at the schools where they teach. We observed one lesson that the teacher presented and a longer individual interview was conducted with each of the teachers.

Data analysis

The data were analyzed by using a thematic data analysis and inductive coding was used. Data from the different instruments were coded according to the coding system of Saldaña (2009). This was done by coding data and grouping codes into categories and eventually into themes. From these themes, nine design principles were formulated for an indigenous knowledge intervention based on socio-constructivist pedagogical strategies.

FINDINGS AND DISCUSSION

The design principles for indigenous knowledge interventions based on socio-constructivist pedagogical strategies which was distilled from the data, are as follows:

Longitudinal professional development within communities of practice, is desirable

One of the main restrictions of the IK intervention reported on in this study, is that the development that took place during the short course was not sufficient. The Bernstein report (2011, p. 22) states that short, workshop-type interventions are inclined to have little value as teachers easily fall back into old patterns. Teachers were not entirely able to apply the socio-constructivist pedagogical strategies taught during the short course or to integrate IK into the content of the Life Sciences curriculum after the intervention. Thus, the first design principle is that future interventions should provide additional support to participating teachers by making use of online platforms such as eFundi and Blackboard (forming online communities of practice). Teachers within these communities of practice can provide mutual support and share ideas (Bernstein report, 2011, p. 22).

Internships to develop practical laboratory skills is necessary

During the study it was found that most of the participating teachers teach at under-resourced schools, and they also indicated that they were not well trained in basic laboratory skills. In the Bernstein-report (2011, p. 23), it is suggested that a context of discovery-learning and experimenting during a professional development programme for teachers can contribute to the quality of the programme. In the context of a three-day short course this is almost impossible as the time is limited. It is thus suggested to involve teachers in internships aimed at developing their practical laboratory skills and exposing them to ways in which basic experiments can be done without expensive laboratory equipment. Pretorius (2015) reported on a programme called the *A-Team*, where science teachers in the broader Johannesburg were involved at the African Centre for DNA Barcoding (attached to the University of Johannesburg) over a long term. They were exposed to the work of scientists and the nature of scientific processes. Similarly, teachers in Ohio in the USA were given the opportunity to work with scientists in research laboratories in the Ohio School Project (Pretorius, 2015). This provided teachers with a more nuanced view of the nature of natural sciences and developed their laboratory knowledge and -skills. If such an internship forms part of a professional development programme, teachers will be able to introduce learners to a more realistic laboratory experience. These internships may be done in school holidays.

Reflection and classroom action research, must be emphasized

The data gathered pointed to teachers having very poor reflection skills – which would make a stronger focus on reflection skills crucial. Therefore, it is suggested that classroom action research should form part of the portfolios submitted by the teachers after the interventions. Classroom action research is described by Gravett and De Beer (2015, p. 344) as the midway between teacher reflection and traditional educational research. Literature points to classroom action research as a vehicle for improving classroom practice, and making teachers more reflective practitioners. The “FINNABLE” project (Pretorius, 2015) an initiative of the University of Helsinki in Finland, is an excellent example of a project focusing on reflection and classroom action research.

Various role players must be involved

The IK interventions will be more successful if there is more involvement from a variety of role players such as principals of schools, school governing bodies and SMTs, as it will increase participating teachers’ motivation. A study by Pretorius (2005) shows that, where principals were involved in professional development programmes, better results were obtained. The short courses in this research were presented (thanks to grants by the NRF and Fuchs Foundation) at a minimal fee, but liaison with SETA (Services Sector Education and Training Authority) will make it affordable for teachers to attend such short courses in future.

Parallel sessions with small groups of teachers per session

The sessions during which the short course content was presented were overcrowded, and this made it almost impossible for the facilitators to give individual attention to teachers. It is suggested that the participating teachers be divided into smaller groups who then attend parallel sessions. Facilitators (experts on each of the different topics presented) present sessions at the same time, to smaller groups of teachers. This will create the opportunity for facilitators to focus on the development of each of the individual teachers.

Supply teachers with basic resources and thorough training on using these resources

The majority of the participating teachers reported on teaching at under-resourced schools and having very little resources to their disposal. During the visits to the schools of participating teachers, it was observed that some schools do not even have sufficient text books and desks for all the learners in the class. Participating teachers identified limited resources as being one of the restrictions to indigenous knowledge education and teaching using socio-constructivist pedagogical strategies. Resources should ideally be made available to less fortunate schools and teachers can be trained in the use thereof in the classroom. This principle was already addressed during phase 2 of the interventions (this paper does not report on this phase) thanks to a grant received from the Fuchs Foundation. This is, however, not sustainable unless the Department of Basic Education becomes involved.

Involve holders of indigenous knowledge in teacher training

One of the factors which hinder indigenous knowledge education that emerged from the data was the fact that indigenous knowledge is not documented and thus not available to everyone. This may be overcome by including holders of indigenous knowledge – not only during the short course, but also in the online community of practice. This will give teachers the opportunity to make use of the expertise of these people when developing their lessons. In the interventions reported on in this study, experts in indigenous knowledge from the Mphebotho Museum (Jautse *et al.* 2016) were used (to a certain extent) and this led to the authenticity of learning material.

Larger emphasis on ways in which *science-on-a-shoestring* can be used in the Life Sciences classroom

Teachers report on not doing experiments in their classrooms because of a lack of resources. However, according to Hattingh, Aldous and Rogan (2013) practical work is not significantly dependent on the availability of resources and that motivated teachers do so despite poor teaching and learning resources. *Science-on-a-shoestring* – the use of cheaper alternatives for expensive laboratory equipment – may contribute to a solution for this problem. The learning guide supplied to teachers during the short course contained methods in which cheaper alternatives for experiments with expensive laboratory equipment were provided. However, they had very limited opportunity to practice, ask questions and experiment with these themselves. During the laboratory sessions, teachers can possibly work in groups with one performing the experiment with laboratory equipment and the other using cheaper (“shoestring”) alternatives.

Stepwise submission of portfolios to ensure larger participation

Only a very limited number of portfolios were submitted by participating teachers after the short course, and in some cases the quality was very disappointing. A totally different way of portfolio submission is proposed. The online platform suggested earlier, can be used for submission. Instead of one submission of the complete portfolio, different assignments which make up the portfolio may be submitted online on different dates. This will ensure better quality portfolios and enable facilitators to give more prompt feedback to teachers.

FACTORS THAT PROMOTED AND HINDERED TEACHERS’ PROFESSIONAL DEVELOPMENT AND THE IMPLEMENTATION OF NEWLY ATTAINED SKILLS

Teachers reported that indigenous knowledge as prior knowledge, promotes the teaching and learning of Life Sciences education: *“Learners relate more to things they know and will definitely learn more if they can relate to the things the teacher is talking about other than talking more about things they don’t know and have never seen”*. Teachers also see indigenous knowledge as a good foundation for practical work in the Life Sciences classroom: *“Yes, because in the classroom we can use chemistry for testing those plants or medicine”*. Furthermore, teachers reported that the knowledge and skills obtained during the short course, empowers them to teach indigenous knowledge and use socio-constructivist pedagogical strategies: *“... I’ve never realized that indigenous knowledge can really make your class to be fun. I’m going to implement it ... I was just teaching the theory ...”*

Teachers, however also report a lack of resources as a hindering factor for indigenous knowledge teaching. Teaching indigenous knowledge is hindered by the fact that it is not formally recorded (*“It is not documented and thoroughly researched.”*) and that CAPS does not provide guidance in this regard (*“Life science in the classroom is taught based in CAPS. It should be catered for first in CAPS curriculum.”*). Negativity of role players and misconceptions on indigenous knowledge also lead to teachers shying away from teaching indigenous knowledge: *“Attitude of learners.”*; *“Misconceptions, religion, beliefs ...”*; *“At the beginning they had a misconception that the indigenous knowledge means witchcraft and muthi ...”*

Teachers reported on being willing to use socio-constructivist pedagogical strategies as they realize the positive effect on the holistic development of learners: *“I have learned that problems from learner’s environment may enhance learning.”*; *“... it is important because it helps learners thinking and processes.”* They also realized that socio-constructivist pedagogical strategies encourage learners to get involved with learning content and that it promotes SDL: *“When working towards answering a question, it is motivating.”*; *“A more learner-centered approach, as a facilitator you also learn from learners.”*; *“... We want to produce learners that are independent ... they must be able to*

respond to the situations within which they find themselves. With the knowledge which they have acquired at school, they must be able to make a living."

CONCLUSION

The purpose of this research was to develop design principles for an IK intervention based on socio-constructivist pedagogical strategies. From the data, nine design principles were developed which may inform future IK interventions. The data that was gathered indicated that a number of factors promote and hinder the incorporation of IK and the use of socio-constructivist pedagogical strategies in their teaching.

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USING THE FLIPPED CLASSROOM MODEL TO FACILITATE STUDENT INTERACTION AND TECHNOLOGY INTEGRATION

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ABSTRACT: The potential of the flipped classroom approach to engage students in higher order critical thinking skills has been one reason this approach has gained momentum as an instructional method. However, what is not yet clear in the available literature is how to design activities for effective interactions. The purpose of this study is to develop and describe a pilot teaching sequence using the flipped classroom model (FCM) for conceptual understanding of pre-service teachers in geometrical optics. Design based research methodology was followed. A cohort of third-year physical science students (N = 93), enrolled in a Bachelor of Education degree programme at a South African University was used as participants and had been exposed to a one semester-long geometrical optics course. The initial findings of the study showed that it is not always the case that basic knowledge is acquired outside lecture time when students watch videos lectures as presumed in FCM, but in-class discussion sessions may also be necessary for the development of factual knowledge, even though the main purpose is to develop conceptual knowledge.

Keywords: Flipped classroom model; teaching sequence; design based research.

BACKGROUND TO THE STUDY

The Flipped classroom model (FCM) is considered as a method of teaching where classroom time is used to engage students in activities beyond memorisation of basic knowledge. This model encourages higher order thinking processes. The FCM expects the student to acquire the basic facts, skills, or concepts outside the lecture time at his or her time of convenience. Many researchers pointed out the potential benefits of this revolutionary method of teaching (Alsowat, 2016; Ogden et al., 2015; Kim et al, 2014). However, the majority of these research findings are based on conducted surveys meant to solicit students' opinion, while some are comparative studies between the traditional method and the flipped method (O'Flaherty & Phillips, 2015). Others use the FCM as an instructional intervention so they could measure gain in conceptual understanding after the instruction (Ryan & Reid, 2015; Lemly et.al., 2013; Bates & Galloway, 2012). A major problem identified in the literature by these authors is the lack of studies that focus on the design aspect of the FCM in order to reveal its effectiveness. In their view (p 94), *"...an emerging barrier for staff to do this (i.e. implementing the flipped classroom model) meaningfully seems to be a lack of pedagogical understanding of how to effectively translate the flipped classroom concept into practice"*. This view is supported by Bane (2014), who highlights the existence of numerous articles in the literature but most of which do not focus on how to design a "flipped" course using proven design principles. Kim et al (2014), with regard to this problem with the available literature, recommended the need for research that spells out on what aspects of the FCM tend to benefit teaching and learning. Flipped classroom model has two major phases in which knowledge is acquired namely, student interaction with learner materials outside the class and, interactions during classroom time. What is not yet clear in the available literature is a specification of how the activities in both phases can be designed for effective interactions. In other words, what activities are needed, how can they be organised, and what instructional tools are effective with this model? Kim et al (2014) suggested research in design specifications of elaborated strategies that can facilitate student interaction and technology integration as one way of examining the effectiveness of the flipped classroom model.

The purpose of this study was to develop a pilot teaching sequence for pre-service teachers in a geometrical optics course using the flipped classroom model that can facilitate student interaction and technology integration.

THEORETICAL FRAMEWORK

According to Applefield, Huber & Moallem (2000), constructivist theory of learning can be used as framework to develop attributes such as the ability to examine, question, and analyse tasks, which enable a student to reach to a meaningful conclusion of an assigned task. According to these researchers, when learners are exposed to experiences which engage them in a process of constructing individual interpretations, the process becomes a meaning-making search leading to learner conceptions of knowledge.

In other words, Applefield, Huber & Moallem (2000) are showing us that the search for meaning-making is a process leading to greater conceptual understanding of content. Engaging learners in activities leading to construction of individual interpretations entails exposing them to experiences or tasks where solutions are obtained through examination, questioning and analysis of such tasks. Activities leading to mastering such abilities are therefore key to knowledge construction for the learner. Such activities are underpinned by the constructivist theory of learning. According to Taber (2012), constructivism provides a theoretical platform from which effective pedagogy can be designed for classroom teachers. The designing and development of this pilot teaching sequence was entirely drawn from what has been proposed by the constructivist learning theory as the theoretical framework.

RESEARCH METHODOLOGY

A design-based research methodology was used, an approach to educational research that seeks to provide means for developing innovative teaching and learning environments, and at the same time also seeking to develop contextualised theories of learning and teaching (Psillos & Kariotoglou, 2016). The design of this pilot instructional sequence and its activities followed five design principles (Goldberg, Otero & Robinson, 2010):

- Learning builds on prior knowledge
- Learning is a complex process requiring scaffolding
- Learning is facilitated through interaction with tools
- Learning is facilitated through interaction with others
- Learning is facilitated through establishment of certain specific behavioral practices and expectations

All principles of Goldberg et al (2010) were incorporated in the proposed instructional sequence in table 1. In phase 1, literature was used to source out the general misconceptions held by students about each unit to enable the instructor to design activities that could possibly diminish the misconceptions, thus building learning on prior knowledge. Scaffolding the learning process makes things less complex and was catered for at phase 3 by giving guidance to students when they engage in discussion activities. Technology integration involves use of tools that facilitate learning where such technological tools allow students to have access to lectures at their own time through online facilities indicated in phase 2. Provision for interaction with each other is given at phase 3 during in-class activities where students debate ideas with supporting evidence. The last principle is on establishing specific behavioural practices and expectations. Students were expected to express ideas openly supported by evidence, and to question ideas of others openly during whole- class or group discussions. This process also took place at phase 3 of the proposed instructional sequence. Using the principles outlined by Goldberg et al (2010), the following instructional framework was designed for delivering the course content:

Table 1: Proposed instructional sequence

Instructional strategies using flipped classroom model for each unit	
<p>Phase 1 Instructional strategies at the beginning of each unit:</p> <ul style="list-style-type: none"> • Identification of the official curriculum to be taught • Identification of students' misconceptions from literature • Identification of instructional goals 	<p>Phase 2 Instructional strategies prior to lesson time:</p> <ul style="list-style-type: none"> • Learner-instructor interaction during pre-class orientation on what the unit is about and how it will be taught • Learner-instructor interaction on grouping students into collaborative groups for collaborative work during in-class and out-of-class activities • Technology integration using online facilities for dissemination of learning materials such as video lectures and other resource materials • Learner-content interaction through video watching of recorded lectures related to the unit
<p>Phase 3 Instructional strategies during lesson time:</p> <ul style="list-style-type: none"> • Students write a verification quiz evaluating level of interaction with learning material posted online. • Instructor dispatch discussion activities • Learner-learner interaction with activities as collaborative group work • Learner-instructor interaction with instructor as facilitator during group discussions • Learner-instructor interactions through whole-class discussions or presentations of discussed activities 	<p>Phase 4 Instructional strategies post lesson time:</p> <ul style="list-style-type: none"> • Learner-content interaction through homework activities to allow students to examine content discussed in class • learner –instructor interaction using blackboard technology for communication • Learner-Learner interaction encouraged using what's-app groups to work collaboratively outside class
<p>Phase 5: Identification of learning support material for each unit</p> <ul style="list-style-type: none"> • Videos lectures with content suitable for each unit and according to the needs of students-online or personal • Online facilities to upload the videos personally made or procured elsewhere and general communication with students • Textbook(s) & websites that students can refer to in support of learning process • Course outline <p>Discussion worksheets with problems of increasing complexity</p>	
<p>Phase 6: Student assessment and review of instructional strategies</p>	
<p>Formative test for unit 1</p> <ul style="list-style-type: none"> • Quiz testing basic physics concepts of the unit • Test on ray model of light • Identification of poorly performed areas through item analysis of formative test • Review of interactional activities 	<p>Formative test for unit 2</p> <ul style="list-style-type: none"> • Quiz testing basic physics concepts of the unit • Test on refraction of light • Identification of poorly performed areas through item analysis of formative test • Review of interactional activities.
<p>Formative test for unit 3</p> <ul style="list-style-type: none"> • Quiz testing basic physics concepts of the unit • Test on reflection of light • Identification of poorly performed areas through item analysis of formative test • Review of interactional activities. 	<p>Summative test for the entire course</p> <ul style="list-style-type: none"> • Test on all three units • Identification of poorly performed areas through item analysis of summative test • Review of interactional activities

Research participants

The participants were 93 third year pre-service teachers enrolled for a Bachelor of Education Physical Science degree at one South African University. All students enrolled for this degree are required to take up a course in geometrical optics at third year level. This course is offered during the first semester of the year. The lecturer had taught the same course for a period of four years.

Research instruments

Two types of instruments were designed and used to collect data, namely a formative test and a summative test. A test becomes a formative instrument when the data collected using it is used to improve instruction. The aim is to come up with an instructional tool that addresses the needs of the students (Haley-Speca, 2016).

There were three formative tests written by students in this study. Each test corresponded to a particular unit of the course. Twelve items were in the first formative test and were about the concept of light, while the second test with six items and, the third one with thirteen items, were about refraction and reflection of light respectively.

According to Hamilton et al, (2009), the word summative has more to do with the purpose for which an assessment is used than the type. It is meant to help the instructor with information necessary to provide judgement of the knowledge and skills of the student at a certain point in time.

The summative instrument was a test given at the end of the instruction of the course as an end of semester examination and had eight items in it. Its main purpose was to provide supporting evidence for a final decision on students' competence to be made. Students were tested on concepts and application across the entire course content.

To ensure validity of the results, tests were subjected to content validity by engaging an experienced senior physics lecturer in the department to check on the extent to which the items in the tests represented the course objectives. Reliability was estimated by calculating the phi (lambda) dependability index (ϕ). This is an agreement coefficient dependent on the cut-point of the tests. In this study the cut-off point was taken as 50%. The index measures internal consistency or homogeneity of items in a test and was found to be ϕ (0.50) as 0.92.

Data Collection Procedure

The tests were administered under the strict supervision of the instructor and other departmental colleagues. The final end of semester examination was administered under the normal university timetable for all examinations written at the end of the semester. The test items were then scored using a marking guide on which a criterion for correct responses was laid out. A range of scores was allocated to each of the items where each item measured a clearly defined objective. All tests, both formative and summative had duration of one and half hours.

Data Analysis

Analysis of data was done using item analysis. Item analysis seeks to measure how well a test or an examination has performed against a background of specified objectives. These objectives form the criterion or the standard on which the success or failure of the student is measured. A test measures the degree to which a candidate has mastered course content relative to specified standards. This helps to plan for future learning (Mhairi, 2002). Classical Test Theory (CTT) was used as framework for data analysis in this study. It is used when describing the statistical characteristics of items in a test. A test score is the sum of the individual item scores. An individual item is of interest through its effect on the total test score (Sohn, 1993). This helps identify problematic areas in content studied and reorganise the instructional process.

Item analysis involves use of item statistics such as item difficulty (p). Item difficulty (p) is determined by dividing the total number of correct answers (R) on an item by the total number of responses (N) to that item. The value can be converted to a percentage or left as a fraction in decimal format. Item difficulty is calculated as: $p = \frac{R}{N}$ which represents the proportion of examinees

that answered the item correctly (Rivera, 2011). The CTT statistical method is considered computationally simple, less expensive, and applicable to small sample sizes, and as such was used in this analysis. The level of difficulty of the items is classified according to table 2 below:

Table 2: Interpretation of Item Difficulty Index (Bichi, 2015)

Difficulty index (p)	Interpretation
$p \leq 0.30$	Difficult
$0.31 \leq p \leq 0.70$	Moderate
$p > 0.70$	Easy

RESULTS AND DISCUSSION

Instead of showing results of all four tests, only one table is provided in this study showing the results of one test. The reason being all four tests were analysed in the same way and their results have a similar presentation as provided in table 3. The only difference would be their areas identified as problematic to students, which will be simply mentioned as part of the findings of the study.

The first formative test to be written by students was about the concept of the ray model of light. This test was measuring the level of mastering by students of the content studied in the first course unit. Table 3 shows the test had 12 items. It also shows some of the competencies students were expected to master. The level to which students mastered these competencies is presented as item difficulty (p).

Table 3: P-values for the formative test about ray model of light

Item number	Item difficulty (P)	Competencies (Knowledge and Skills Assessed)
1	0.41	Defining a ray as hypothetical construct depicting flow of light energy in straight line and its graphical representation
2	0.56	Interpreting ray model assumptions
3	0.26	Using ray definition in unfamiliar situations
4	0.42	Predicting behaviour of light using limitations of ray model
5	0.11	Using appropriate model of light in unfamiliar specified situation
6	0.44	Using ray model assumptions to explain reflection by surfaces (at macro-level)
7	0.49	Explaining the cause of diffuse and specular reflection in relation to wavelength of light (at micro-level)
8	0.68	Using ray model assumptions to explain why an object can be seen by more than one person at the same time
9	0.37	Using Snell's law to predict reversibility of light
10	0.76	Interpreting graphical representations of models of light
11	0.59	Identifying and stating the three laws of ray optics: rectilinear propagation of light, law of independence of light rays, and law of reversibility of light rays
12	0.39	Identifying and stating the three laws of geometrical optics: rectilinear propagation of light, law of reflection, & law of refraction

Table 2 presented earlier on was used to interpret the level of difficulty of items in table 3. Figure 1 shows a histogram of the items in table 3 grouped under the three categories of table 2: Easy, Moderate and Hard. It also shows how students performed at each cognitive level, in terms of Bloom Taxonomy, for each particular category. Of the twelve items presented in the test, only one (8%) at comprehension level was easy for the students ($p > 0.70$). There were no application and knowledge items easier for students, hence the bar graphs indicate zero values respectively. Two (17%) application type items were hard for students ($p < 0.30$), while comprehension and knowledge type items were neither easy nor hard as shown by zero values on the respective bar graphs under

this category. The remaining nine (75%) items, four knowledge and five application type were moderate ($0.30 < p < 0.70$). No item testing comprehension fell into this category.

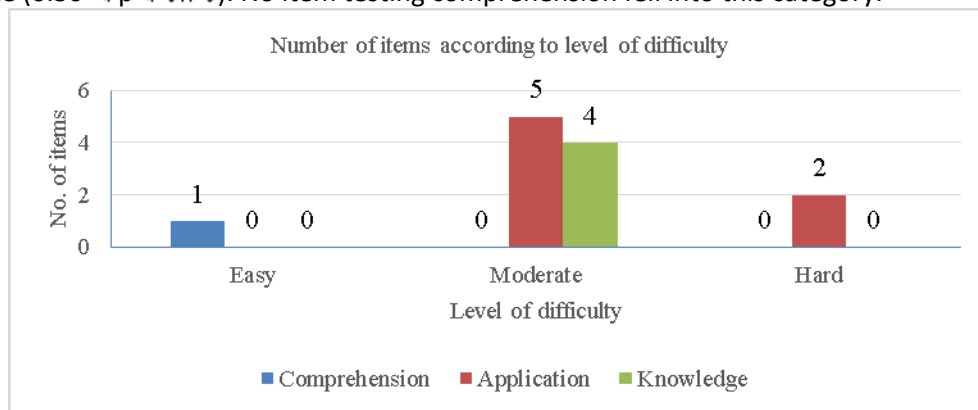


Figure 1: Test items arranged according to level of difficulty and cognitive levels

The anomaly in these results is that the knowledge items were expected to be easier than items measuring comprehension since students were expected to simply recall facts, but the comprehension item which required students to interpret concepts was much easier for the students.

INSTRUCTIONAL IMPLICATIONS

These results show that during instruction teaching of basic facts cannot be simply ignored assuming students can easily capture these facts from the video lectures submitted online before coming to class. During in-class discussions, there is need to include interactional activities that also assist students building primary concepts that are foundational to use of higher order cognitive processes. The view by the FCM proponents that learners come to class with basic knowledge acquired from material posted online may not always be the case, even though quiz activities may have been used to promote learner-content interaction online.

Another observation was that the formative test was a criterion referenced test where students were aware of what was to be tested before they wrote the test. Students were expected to find the test easier, but more than half of the students did not reach the cut-off point. This compelled a review of the teaching strategies employed both for lower and higher order activities provided to students.

CONCLUSION

The purpose of this study was to develop a pilot teaching sequence that can facilitate student interaction and technology integration using the FCM. The model assumes mastering of basic concepts by students outside the classroom environment. However, the study found students struggling with basic concepts, of which the impact of lack of this basic knowledge has a negative bearing on solving higher order questions. It can therefore be concluded that it is not always the case that basic knowledge in FCM is acquired out of the lecture time. Thus in-class discussion sessions may also be necessary for development of factual knowledge.

In order to improve the following teaching sequence, the first in-class discussion session after writing a quiz would be dedicated to discussing the basic facts, concepts and principles through exercises that mainly promote recall and comprehension of this basic knowledge. Thereafter in the following sessions students are engaged in higher order activities.

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SCIENCE TEACHER BELIEFS AND ITS IMPACT ON TEACHING SCIENCE

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ABSTRACT: In the South African education system, research has revealed that although a change in curriculum was announced in the post-apartheid era, many teachers still continued with existing traditional teaching practices, with a little tweaking to show that they had modified their teaching to the required style. The speed of educational transformation is therefore seriously slowed down. A case study design was used to conduct this research. All participants in the study responded to open ended questionnaires and thereafter were interviewed. The study aimed at answering the following research question: What are the teacher's beliefs with regard to teaching and learning Physical Sciences in a grade ten class? The study indicated the positive experiences that teachers encountered in their past greatly influenced their classroom practices even when it did not fit it with the curriculum reform.

Keywords: Teacher beliefs; physical sciences; classroom practices

INTRODUCTION

In the South African context, the shift from the traditional content-driven curriculum to one that is more learner-driven and inquiry-based has affected many teachers' classroom practices. Physical Sciences is greatly influenced by the human resource, i.e. sufficiently trained Physical Science teachers should be effective in teaching the subject and assessing learner performance both adequately and appropriately (Mchunu, 2009). Teacher's beliefs on teaching and learning Science have had a pervasive influence on their classroom practices (van Driel, Verloop, & de Vos, 1998). Science teachers have developed their own conceptual frameworks through their years of teaching. Consequently, their teaching practices seem to be consistent with these frameworks (Brickhouse, 1990). The conceptual framework that these experienced teachers developed include knowledge and beliefs about Science, subject matter, teaching and learning, and learners that are all interrelated in a coherent manner (Brickhouse, 1990). Novice teachers are mentored by experienced teachers. As a result, the experiences of these novice teachers' conflicts between their personal views of Science and Science teaching on the one hand and their personal classroom practice on the other (Brickhouse & Bodner, 1992).

LITERATURE REVIEW

Physical Science teachers who are knowledgeable about the nature of Science play a central role in promoting functional scientific literacy in society (Ramnarain, 2013). Physical Science teachers must make use of multiple pedagogical strategies to transform their existing knowledge of the subject content into a form that can be easily understood by learners. According to Pajares (1992), the decisions individuals make throughout their lives are based on their beliefs therefore it is argued that teacher beliefs influence their views of teaching during classroom practice (Pajares, 1992). Oliver and Koballa (1992) are of the view that teacher beliefs are associated with knowledge, attitudes, and personal convictions, or are reflective of one's acceptance or rejection of a proposition. The belief of an individual influences their life and actions, and as a result the beliefs of Science teachers also play a role in restricting Science education (Lumpe et al., 2000). Teacher beliefs originate from their life experiences. Teachers that have been in the education sector for decades gain experiences that contributes to the formation of strong and enduring beliefs about teaching and learning (Richardson, 1996). These experiences include personal experiences, experiences with schooling and instruction, and experiences with formal knowledge (Richardson, 1996). The beliefs of

teachers must not be ignored, if the recommendations of policy are to result in enduring change in the classroom (Lumpe et al., 2000). The alternation of belief of a teacher can be very difficult to achieve (Earley & Bubb, 2004). Teachers will only take ownership if they are involved in and committed to the process of educational change. Beliefs are difficult to change overnight. According to Morgan and Xu (2011), teachers' beliefs about teaching and learning are often identified as an obstacle to the successful implementation of curriculum reform.

Existing research studies have revealed that teachers' epistemological views of science influences how Science is conducted and portrayed in the classroom (Lederman, 1992). Lederman (1992), further states that the teachers' scientific epistemological views are often consistent with their instructional beliefs and practices. Teachers form and develop classroom practice theories based on personal experiences gained in their classroom practices over the years (Lotter et al., 2007). However, it is also possible for teachers to form and develop classroom practice theories during the period of being learners. According to Calderhead and Robson (1991), when teachers go through the pre-service training some hold onto vivid images of teaching from their experiences as learners.

Teachers' classroom practices grow with experience and time. With this the teacher's knowledge expands and becomes more coherent and as a result a highly personalized pedagogy or belief system is developed that actually controls the teacher's perception, judgement, and behaviour (Mansour, 2008). It is further noted that to change the beliefs of a pre-service teacher is far easier than that of an experienced teacher (Tschannen-Moran, Woolfolk Hoy, & Hoy, 1998). According to Lotter et al. (2007), teachers who believed in a "hypothetico-deductive philosophy of logical positivism" taught science as a collection of facts. Thus the use of scientific processes skills was very limited in such teachers' classroom practices. According to Tsai (2002), teachers who use the traditional category taught science by merely transferring knowledge from teacher to learner. These teachers become "experts" of the content knowledge consequently passing it in to learners as complete scientific facts, with no room for interrogation. The learner is a passive recipient of knowledge. Laplante (1997), posits that teachers' epistemologies are passed onto learners as their own, with some teachers believing that "school science" is separate from "real science". With this approach in mind, the teacher's focus is therefore more on the mechanical delivery of the curriculum. Resultantly, these kind of teachers would normally adopt traditional approaches in their classroom practices rather than innovative practices. Innovative practices make use of constructivism, which involves learning that occurs through personal experience. Providing opportunity for learners to be actively engaged in an activity, drawn from previous knowledge and construct new meanings. Thus, the knowledge that all individuals possess is a function of their experiences and beliefs (Jonassen, 1991). Using this type approach in classroom practice in Physical Sciences allows for "major paradigm shift" in the subject (Mchunu, 2012, p. 106). Teacher's beliefs of teaching science are also placed into a process category whereby science is taught by placing emphasis on the processes of self-discovery and problem-solving procedures (Tsai, 2002). In order to teach Science using process skills and therefore the inquiry method, it is beneficial to have a proper conceptual understanding of inquiry teaching. The fundamental nature of the inquiry approach is a very hands-on approach. It is aimed at teaching Physical Science learners skills of problem solving, making observations, collecting, comparing and analysing data, building on existing content and constructing new ideas and synthesising and evaluating conclusions (Loucks-Horsley & Mutsumoto, 1999). By allowing learners opportunity to conduct experiments in the classroom is in fact allowing them the opportunity to coordinate the use of their content knowledge and scientific skills. Lotter et al. (2007) revealed that teacher beliefs about Science, the teaching process, and the learners all influence the choices teachers make during classroom practice. Teachers who perceived the concept of "inquiry" as a thinking process had adopted classroom practices that involved a questioning pedagogy, and as a result the classroom discussion was mostly teacher-lead discussions.

METHODOLOGY OF RESEARCH

Design

A qualitative case research design was adopted. The case study helped to ensure that teacher beliefs on teaching and learning are not explored through a single lens and rather an assortment of lenses (interviews, observations and questionnaires). The conceptual framework used for the study was concerned with understanding human practices (teacher's classroom practices) within a social context (the school), from the teacher's point of view.

Area of the Study

This study was undertaken in the Republic of South Africa (RSA) in the province of Kwa-Zulu Natal.

Data Collection and Management

Data were collected by means of questionnaires, lesson observations and teacher interviews. Data were then analysed using the typology approach. To ensure rigor, all data collection instruments were piloted. Ethical considerations were accounted for in this study.

RESULTS

The case of Ms Avos: Ms Avos was very firm in her beliefs about learning Physical Sciences, due to the success she had experienced when she herself was a student. By understanding the teacher's attitudes and beliefs, her thought processes and classroom practices could be understood (Richardson, 1996). *"When I was I grade 10 the chemical formulae I learnt by heart in a day for a test after that chemistry was a breeze for me"*. It is only the belief of Ms Avos that if learners memorize the table of cations and anions then chemistry becomes easy. Understanding the charge that each ion has is of importance as its relevance is related to the periodic table and its ability to react. Therefore, it is important to distinguish between the two concepts. Tsai (2010), states that the experiences of teachers when they were once students impose an effect on their beliefs of teaching, and learning science. According to Ms Avos responses to the questions she believed to teach Physical Sciences the teacher must have a good understanding of the content as well as understanding of the learners' capabilities. She articulated a teacher must be passionate about his/her subject. As a teacher she advocated that Physical Sciences could not be taught like subjects such as History, which involved memorization of large quantity facts. However, Ms Avos contradicted herself based on her experiences of memorizing the table of ions. Ms Avos's believed that inquiry teaching involved, *"Learners learn new things by being involved example doing practicals"*. Firstly, Ms Avos, belief of what inquiry learning is, was correct. Woolfolk (2007), defines inquiry learning as an approach in which the teacher presents the learner with a rather puzzling situation and the learner then attempts to solve the problem by collecting data and then testing his/her conclusion (Woolfolk 2007). Ms Avos believed that the initial question and answer session she started her lessons with, was her using the inquiry approach in her classroom, this was not inquiry learning. However, the teacher articulates in her interviews that these sessions were in fact a pre-lesson discussion, based on the content that learners had to read. From observations of the lessons, it was only a small minority of learners that read before coming to class, and it was this small minority who were seated at the front of the laboratory that participated in the lesson. The teachers' belief that inquiry learning could only work well with small class sizes was reiterated when she described her initial years of teaching Physical Sciences with a grade twelve class. Lortie (1975), states that to change a teacher's beliefs is often difficult because the beliefs of teachers are based on their practical teaching knowledge that is learned over many years of classroom experience; and it is this knowledge that drives the decisions they make in the classroom.

The case of Ms Sassy: According to Ms Sassy her classroom practices of today is attributed to her mentor. Based on Ms Sassy's response to the questionnaires her beliefs on the founding principles for teaching and learning Physical Sciences at grade 10 include the use of, *Inquiry, experimentation*

and research. Ms Sassy's beliefs were triangulated with her actions during her of teaching and learning Science. During lesson observations of Ms Sassy, she paired learners into groups and assigned them the task of researching the discoveries made by various scientists on the atom. The learners then had to present their findings to the class. Ms Sassy, was of the belief that learners needed to be responsible for their learning, hence she had encouraged group work and research, and thus her beliefs fostered the delegator teaching style in her. In Ms Sassy's questionnaire response she had indicated that her learners only matured towards the latter part of the year, *Not mature enough for grade ten Physical Sciences...they mature later in the year.* Because the teacher was so set in her beliefs of learners needing to take responsibility for their learning she failed to take into account the maturity and cognitive development of her learners. The teacher delegated them with a task (researching the discovery made by particular scientists) that proved to be more fact based learning and acceptance rather than critical engagement with the content which resembled that of the apartheid education (Seroto, 2004). This was observed when Ms Sassy made use of the idiom, *you all missed the boat.* The teacher implied that the learners had failed to understand the objective of the whole exercise. Chilembe and Bruce (2015) state that when the teacher adopts the delegator style of teaching in his/her classroom practice although the aim is to develop autonomous learners, it is essential the maturity of the learners is taken into account.

The case of Mr Hill: It was the belief of Mr Hill that a good teacher is one that, *"Is committed and dedicated, well versed in technological skills (comp, smartboard) has a desire for his/her learners to succeed, love and passion for teaching."* Mr Hill maintained good classroom management through the use of his autocratic communication style; however, his classroom practice involved a tremendous amount of lecturing, question and answer sessions and demonstrations.

Mr Hill, became a teacher because he describes it as, "It was a calling". Therefore, Mr Hill had an intrinsic motivation to teaching, he did it because of the pleasure and satisfaction that accompanied the action (Ryan, Connell and Deci, 1985). He wanted his learners to be motivated because he believed that when they are motivated they will be dedicated. His belief to doing well in Physical Sciences was through, *"Practice, practice, practice!"* He further alluded to teaching Physical Sciences through, *"Self-discovery is the ideal way for teaching physics. Science is all about testing theories."* To Mr Hill, learners posing questions to him or vice versa was considered inquiry teaching. Mr Hill conceptual understanding of inquiry teaching was "asking questions". However, Mr Hill was in fact using the traditional method of teaching. Mr Hill believed that issues of discipline created a hindrance to his teaching, and it resulted in him sending learners out of the class. It is against regulation to send learners out the class due to poor behaviour, thus Mr Hill adopted his autocratic approach in his class. Mr Hill's belief on learning was, *"Learning is when a child is able to do things on their own."* But the teacher did not create learning opportunities for the learners to do things on their own. Mr Hill described his best teaching experience of Physical Sciences when he was based at a school in London. Mr Hill alluded to the extensive use of technology and video simulations that was used as teaching aids during his lessons. Goddard, Hoy, and Hoy (2000), infer that the teacher's beliefs influence his learning environment. Mr Hill beliefs on the use of such technology helped to enhance his teaching, his learners understanding.

DISCUSSION

Case 1 - Ms Avos: During lesson observations of the teacher, she emphasizes the memorization of the table of ions rather than understanding the manner in which ionic charges were derived. The teacher perceived this as being the best way to learn how to write chemical formulae. This was because of the manner in which it was taught to her as a learner during which the status quo was the traditional method of learning. As a result the beliefs of Ms Avos towards the learning of Physical Sciences influenced the way she taught the subject. Ms Avos was never given the opportunity to challenge her beliefs because there had been no grade 10 professional development

that focused on subject matter knowledge about teaching Physical Sciences. Ms Avos believed that if she engaged in classroom practices such as group discussions, it would be an opportunity for her learners to socialize. Consequently, Ms Avos did not believe in learning by social constructivism. The researcher infers that in order to change the beliefs of Ms Avos, professional development workshops that cater for the needs of the teacher for the given grade needs to be implemented. Ms Avos was a product of the Content Based Education during those years of apartheid education system in South Africa. She was introduced to lecturing and rote learning during her days as a learner. Ms Avos had experienced some positive results from being taught using these traditional approaches, and on becoming a teacher, she had to borrow from her experiences as a learner to do her classroom practice in Physical Science. Ms Avos therefore encouraged her learners to use rote learning. Critical theories which needed understanding were instead memorised. Evidently, Ms Avos never encouraged learners to develop their questioning skills, and also develop other related skills. The scientific skills of the learners were therefore severely impeded.

Case 2 – Ms Sassy: Ms Sassy was a direct contrast of Ms Avos with regard teacher beliefs. Ms Sassy believed that classroom practice on Physical Sciences required involvement of the learners. Ms Sassy preached that it was imperative for the teacher to adopt a liberal approach in classroom activities which would promote that "hands on activities" involving experiments and research conducted by learners. Despite this fundamental belief of Ms Sassy, she never implemented her beliefs in her classroom practices. Ms Sassy's classroom practice instead focused on the development of autonomous learners without taking into account the maturity of her grade 10 learners. All what Ms Sassy had was a history of methodological approaches in the teaching of Physical Sciences which she had acquired from her mentor of some 30 years ago. Ms Sassy's involvement of learners during classroom practice was sporadic; she preferred to keep to the traditional classroom practice. Consequently, she remained a hardened conservative of the old apartheid era education in South Africa which promoted lesser learner involvement in classroom practice. Evidently, the teacher was mentored under the apartheid education system with special focus on the traditional content based curriculum. Therefore, the teacher's beliefs impacted on how she performed her classroom practice even beyond the apartheid education system.

Case 3 – Mr Hill: The teacher believed that learners of Physical Sciences need to be autonomous in their learning. Mr Hill believed in structuring his classroom practice to give space to the learners to take charge of their own learning. Despite these efforts, still Mr Hill's classroom practices failed to achieve meaningful learning. The shortcoming was that Mr Hill had placed tremendous emphasis on maintaining classroom discipline amongst his learners. His autocratic teaching approach impeded learner interaction, group activities and open discussions. Mr Hill's classroom practice impeded open communication during lessons, and therefore exposed his practice to curtailing meaningful learning. Based on Mr Hill's description of his best teaching experience, it appears to have such a tremendous impact on him that he is still adopting the same methodology of teaching that he used over three decades ago in a classroom that was well resourced in terms of teaching aids. Richardson (1996), states that teachers' beliefs originate from their life experiences. Mr Hill is currently over the age of sixty, and his experiences that have contributed to the formation of strong and enduring beliefs he has about teaching and learning come from different stages of his educational career (Richardson, 1996).

CONCLUSION

Teacher beliefs on teaching and learning do influence their classroom practices. In the South African schools experienced Physical Science teachers provide mentorship to the younger teaching cohort. The negative might be that if the older teachers passed on negative experiences and misconceptions to these novice teachers, the newer teachers might instead develop negative beliefs in the teaching and learning of Physical Sciences consequently leading to a vicious cycle.

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MEASURING THE IMMEDIATE IMPACT OF TEACHER WORKSHOPS IN NATURAL SCIENCES

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ABSTRACT: This paper reports a study about the effectiveness of the usage of pre- and post-test results to measure the impact of teacher trainings. The aim of this paper was to explore the effectiveness of the pre- and post-tests in measuring the immediate impact of the Natural Sciences (NS) workshops. The research question was: Is there any difference in scores between the pre-test and the post-test during the MSTA teacher trainings? To what extent did the teachers benefit from the NS workshops? A pragmatic paradigm based on the integration of the positivistic and interpretive research paradigms was used to achieve the aim. Consequently, data were analyzed both quantitatively and qualitatively. The p-value was 0.00298 which suggests that the null hypothesis of zero median difference is rejected; the median is significantly different from zero. The data provides sufficient evidence that the teacher workshops had a positive influence on teachers. There were no minimum standards in place for setting a pre- and post-test. Teachers embraced pre and post-testing. Statistically pre and post-testing do measure the impact of NS teacher workshops. Therefore, the paper recommends that since pre- and post-testing can measure the impact of teacher trainings to a large extent, prolonged teacher trainings be initiated; the impact of teacher trainings be traced down to learners; post-testing be conducted months after the training as opposed to the last day of the training.

Keywords: Pre-test; post-test; teacher training; natural science (NS)

INTRODUCTION

A huge budget is invested annually in teacher trainings and therefore assessing the impact of these trainings is critically important. The Department of Basic Education has encouraged teacher trainers to administer pre-test before and post-test at the completion of the training to assess if the training had impact. Teachers attend trainings to upgrade their subject content knowledge, NS teachers being one of the groups of teachers attending the week-long trainings. It is of interest to explore whether such tests are effective in measuring the impact of teacher trainings. Questions that could then be asked are: Is there any difference in the scores between the pre-test and the post-test administered in the teacher trainings? Are teachers learning from these trainings? Is there value for money? Such questions motivated the research to be conducted and reported in this paper.

A long term evaluation of all the O.R. Tambo Mathematics, Science and Technology Academy (MSTA) teacher trainings is still to be conducted to assess the impact of the MSTA teacher trainings on learner performance. However, pre- and post-testing have been conducted since the inception of MSTA to assess if teachers acquired knowledge from teacher trainings.

The aim of this study was to explore the effectiveness of the pre- and post-tests in measuring the immediate impact of the NS workshops. In order to achieve this aim, the research questions were formulated as: Is there any difference in scores between the pre-test and the post-test during the MSTA teacher trainings? To what extent did the teachers benefit from the NS workshops?

Pre-test and post-test were scarcely administered in the past during teacher trainings by the Department of Basic Education in South Africa (S.A). However, recently this practice of pre- and post-testing was introduced and implemented to assess the immediate impact of teacher trainings. The view of using pre- and post-test in teacher trainings is growing at all levels in the Department of

Basic Education ranging from cluster to provincial teacher trainings. This study is one among the few to focus on exploring the extent at which pre and post-testing measure the impact of teacher trainings in South Africa.

LITERATURE REVIEW

Literature on pre and post-testing as well on measuring the impact of training was reviewed in order to answer the research questions. The US Department of Education (n.d.) has a view that “pre-post-tests refer to academic achievement tests that are given to students to assess their academic progress from the beginning to the end of the programme of instruction” (p.4). They also believe that pre-tests reveal the learners’ abilities before entry and provide the baseline in the beginning of the programme training. We align ourselves as writers of this paper to this view because trainers will have to know how deep and wide to go regarding the explanation of some concepts. The depth and width could be determined by the well-designed pre-test. Furthermore, they argue that the difference between pre- and post-tests should reflect the learning that has occurred while in the training. Moreover, they say post testing illustrate the individual teacher’s gain from the training. This is the understanding we share as we administer the pre and post-testing in the MSTA teacher trainings.

In addition, now that we are in an era of technology instead of using traditional way of conducting pre- and post-tests we can explore online ways of conducting pre and post-testing to minimize challenges that are encountered when tests are conducted. For example, challenges of taking long to mark the tests and also accuracy in marking. LaRose and Megginson (n.d.) stated in their paper that online testing went smoothly as there were no logistical challenges; grading was done automatically online and the instructor workload reduced since marking was conducted online too.

The pre and post-testing are used for different purposes by different institutions world-wide. Therefore, the design of the pre and post-test is informed by the purpose thereof and guidelines will be necessary. The US Department of Education (n.d) has written a guide on pre and post-testing. They argue that pre- and post-tests have some benefits and the benefits include; Indicates student progress from a particular programme to keep them informed of their progress, administrators can use the tests to improve programmes, Measure effectiveness of trainings, for reporting purposes and to see where training needs to be improved in terms of the presenter or probably an approach needs to be changed.

The MSTA has been conducting the pre and post-testing and has utilized the combination of the above mentioned benefits. In the main MSTA utilize pre and post-testing to measure the impact of the teacher trainings. There are pros and cons when using pre- and post-test (US Department of Education). Our experience as MSTA is that pre and post-testing indeed consume time. So, proper planning and adequate time is required for the administration of these tests.

METHODOLOGY

The mixed method approach was used to achieve the aim of this research. The paradigm used in this research is based on pragmatism which integrates the positivistic and interpretive research paradigms. This research was conducted in Mpumalanga Province of South Africa in the MSTA teacher trainings. MSTA conducts teacher trainings for the schools in Mpumalanga Department of Education. Data was collected from the NS teacher trainings in 2016 and 2017. All the pre- and post-tests of teachers who attended the workshops that occurred over the winter school holidays were collected. These were then recorded to see if there were any differences between the pre-test and post-tests scores.

The teachers' scores from the pre- and post-tests were analyzed quantitatively using statistical techniques as well as qualitatively using qualitative content analysis of the semi-structured interviews and pre and post-tests records.

In order to determine if there is any difference in marks between the pre-test and the post-test during the teacher workshop training? A null hypothesis was stated as follows:

Null hypothesis: The median of the difference score is equal to zero ($H_0: Me=0$) for both 2016 and 2017 pre- and post-tests. There are several statistical techniques that could be suitable to analyze the quantitative data in this study. Wilcoxon signed-rank test is similar to a t-test where two variables are compared in a single group (Maree, 2017). There are certain assumptions like random sampling, normality, equal variances and others should be considered when using a t-test. However, these are not required when using Wilcoxon signed-rank test. It is against this background that Wilcoxon signed-rank test was used in this study.

According to the recorded data some teachers who attended the training did not write a pre-test, or post-tests or both. Consequently, ten NS teachers were purposefully sampled from each one week-long training conducted between 2016 and 2017 for them to explain in a semi-structured interview reasons that led to them missing a pre-, or post-test or both. They were asked a question as follows depending on whether they missed a pre or post or both tests: What prevented you from writing a pre/post or both pre and post-test? They were at liberty to explain and their responses were noted in a diary and interpreted. Teachers were requested to use codes as opposed to using their actual names in the pre and post-tests scripts. The use of codes was used for ethical consideration purposes. The real names of the teachers who attended the NS workshop were not reflected on the pre- and post-tests scripts but only in the attendance registers for the workshop. The data was then analyzed by two researchers.

RESULTS

Quantitative results

Table 1 and 2 below indicate the quantitative analysis for the results of both 2016 and 2017. This research employed the Wilcoxon signed-rank as a statistical technique to determine if there is any impact brought by pre- and post-tests during the MSTa teacher trainings. The Wilcoxon signed-rank test tables for both years are displayed in table 1 and 2.

Table 1: 2016 NS teacher trainings -Statistical Result Details

W-value:					105
Mean		Difference:			-9.09
Sum	of	pos.	ranks:		105
Sum	of	neg.	ranks:		423
Z-value:					-2.9731
Mean		(W):			264
Standard	Deviation	(W):			53.48
Sample Size (N): 32					
Result 1 - Z-value					
The Z-value is -2.9731. The p-value is 0.00298. The result is significant at $p \leq 0.05$.					
Result 2 - W-value					
The W-value is 105. The distribution is approximately normal. Therefore, the Z-value above should be used.					

The p-value is 0.00298 which is less than 0.005. This suggest that the null hypothesis of zero median difference is rejected the median is significantly different from zero. The data provides sufficient evidence that the teacher training had a positive influence on the NS teachers.

Table 2: 2017 NS teacher training -Statistical Result Details

W-value:				0
Mean		Difference:		-42
Sum	of	pos.	ranks:	0
Sum	of	neg.	ranks:	276
Z-value:				-4.1973
Mean		(W):		138
Standard	Deviation	(W):		32.88
Sample Size (N): 23				
Result 1 - Z-value				
The Z-value is -4.1973. The p-value is 0. The result is significant at $p \leq 0.05$.				
Result 2 - W-value				
The W-value is 0. The critical value of W for N = 23 at $p \leq 0.05$ is 73. Therefore, the result is significant at $p \leq 0.05$.				

The p-value is 0.00 which is less than 0.005. This suggest that the null hypothesis of zero median difference is rejected the median is significantly different from zero. The data provides sufficient evidence that the teacher training had a positive influence on the Natural Sciences teachers.

Qualitative results

The pre and post-tests scores were recorded and they were received. The total number of teachers who attended the NS workshop in 2016 was 66. Out of the 66 only 32 wrote both pre and post tests and this translated to 49% of teachers who wrote both tests. Out of the 66 teachers, 18 wrote only pre- test which translated to 27%. Furthermore, 10 out of 66 teachers wrote post-test only (15%) and 5 did not write both the pre and post-tests which is about 8%.

The total number of teachers who attended the NS workshop in 2017 was 41. Out of the 41 only 23 wrote both pre and post-tests which translated to 56%. Five of the 41 teachers wrote only pre- test which is 12%. Thirteen of the 41 wrote post-test (32%) only. There were no teachers who did not write both the pre and post-tests in 2017 NS teacher trainings. The part of the data discussed is represented in a tabular form as depicted in table 3.

Table 3: Summary of teachers attended the NS teacher training in 2016 and 2017

	2016	2017
No. attended	66	41
Wrote both pre- and post	49%	56%
Wrote only pre-	27%	12%
Wrote only post-	15%	32%
Did not write both	5%	0%

Looking at table 3, it is clear that there is an increase in the percentage of the number of teachers who wrote both the pre- and post-tests from 2016 to 2017. This was interpreted as that teachers are gradually getting used to writing these tests in the trainings. Teachers gave different reasons why they were unable to write a pre- or a post-test or both. Some of the reasons cited were that they arrive late in the training venue because of reasons beyond their control. Some cited common transport as the reason for late coming, some public transport. Regarding the writing of the post-

tests, some claimed they had to leave the training venue earlier due to other commitments. Therefore, could not wait for the post-test to be administered.

Looking at the difference between pre and post-tests scores for some teachers, we concluded that it is not all the NS teachers who attended the MSTA teacher training seemed to have learnt from the training. However, the majority of the teachers had an increase in the score of the post-test. In 2016, out of the 66 teachers who attended the workshop, 7 teachers had lower scores in the post-test as compared to the pre-test. This finding was never anticipated and it was not well understood. Table 4 show teachers who dropped in the post-test in terms of the scores. Specifically, teachers with the following codes; PM 102 had a negative variance of 14; NEC 527 was -49; CZWO was -5; SIS-31; HKZ was -4; TPM51 -1 and BNM was a difference of -26. So, the highest drop is 49 and the lowest is 1. Secondly, it was found that some teachers were not willing to write the pre- and post-test even though they were not required to indicate their real names but just codes. Thirdly, observations were made that some teachers perpetually arrived late in the training venue late so much so that they were unable to write the pre-test. This was evident because about 51% in 2016 and 44% in 2017 did not either the pre and post-test.

Table 4: Seven teachers whose scores dropped in 2016

TEACHERS CODE	PRE TEST %	POST TEST %
PM 102	45	31
NEC 527	59	10
CZWO	69	64
SIS	57	26
HKZ	46	42
TPM51	50	49
BNM	43	17

One might be tempted to believe that the 7 teachers whose scores dropped indicated in table 4 above were better before attending the NS teacher training. The element of guessing could be a factor too. However, literature indicates that people change behavior when under investigation (Leonard & Masatu, 2006). Also, there could be myriad of reasons for the drop in the teachers' scores from pre- to post-test. This could be linked to limitations identified in this study that; the pre and post-tests were multiple choice questions which in our view promoted guessing the answers, though teachers were supervised when writing the pre and post-tests some might have sneaked in others responses without even understanding and reading the questions, well, one may argue that the 7 teachers whose scores dropped were confused most probably because some are not NS specialists so became even more confused after the workshop. Interestingly, it was found that there was no teacher whose score dropped in the 2016 NS group.

There were lessons learnt from literature reviewed that factors that may affect the pre- and post-test writing and it is believed that some of these factors played a role in this study. These factors that may impact pre-post-tests results are; practice effects where teachers take the same tests/questions repeatedly, this could be mitigated by having a pool of questions/question banks to choose from as pre- and post-tests are developed, fatigue effects which could be due to hunger or getting tired as you write the test.

DISCUSSION

The pre and post-testing do measure the impact of teacher trainings to a large extent. Therefore, we recommend that firstly, teacher trainings should be prolonged for them to have impact on teacher content knowledge. Research has proven that teachers do not implement in the classroom what they learnt in the short teacher trainings and workshop (Mayer and Lloyd, 2011; Lumpe, 2007).

However, it is acknowledged that short trainings and workshops could have some benefits like mediating the policies to teachers (Kekana, 2016).

Secondly, pre and post-testing alone cannot be sufficient to measure the impact of teacher trainings and therefore recommend that learner performance on the content teachers were trained on could be considered as well to assess the impact of teacher trainings. We acknowledge that there are a number of factors that affects learner performance (Phakeng, 2015; Campbell & Prew, 2014). In addition, Van der Berg, Taylor, Gustafsson, Spaull & Armstrong (2011) argued that teacher content knowledge is one of the factors. It is our view that teachers are likely to teach the content that they know and are comfortable to teach. Also, we believe this because of what the writers like Barber and Mourshed (2007) have argued that learners cannot be better than their teachers.

Thirdly, we recommend that post-testing should be administered months after the training was concluded. We argue that when post-testing is administered immediately after completion of the training, we might be testing the memorized facts as opposed to the understanding of the content learnt in the teacher training. It is believed what the teachers have learnt would not immediately be translated into knowledge. Guskey (2002) argued that change takes time and effort to be realized.

CONCLUSION

It has been statistically proven in this research that pre and post-testing during teacher training do measure the impact of the teacher trainings. Therefore, pre and post testing are effective tools to be utilized in teacher trainings. Since pre- and post-testing can measure the impact of short teacher trainings to a large extent, prolonged teacher training could be initiated. Other researchers agree with this assertion because short teacher trainings were found to be ineffective and having little impact on teacher knowledge (Mayer & Lloyd, 2011). Research studies in this area will assist the Department of Basic Education to plan appropriately for teacher development and budget for prolonged teacher trainings. Pre and post-testing will not be done only for compliance purposes but will inform the planners of the teachers' actual content needs. This study could be of assistance to trainers and funders of the teachers training programmes who are interested in the progress and improvement on training to those that are trained and funders wish to see value for money.

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A STRATOSPHERE BALLOON EXPERIMENT TO STIMULATE LEARNERS' INTEREST IN THE SCIENCES

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ABSTRACT: There is a huge demand in South Africa and worldwide for scientists and engineers. It is necessary to attract learners to this field of science and technology. Various practical experiments can be used to reach this goal and in doing so the training of students may lead to an increase in the next generation of scientists. In this paper, the planning and execution of a stratosphere balloon experiment with a payload is discussed to address this gap. The experiment may further offer learners various skills, such as group work, listening skills, mathematical skills and scientific skills. Data was collected by means of questionnaires before and after the experiment, as well as the payload data of the balloon. This was done to determine the feasibility of such an experiment as a means to successfully attract learners to science as a potential field of study. The concept of using an experiment such as this is shown as a possible way to make learners more aware of science as a potential career option.

Keywords: Learners; science education; STEM; experiment; atmosphere, Raspberry Pi; weather balloon; payload.

INTRODUCTION

There is a huge demand in South Africa and worldwide for scientists and engineers. For example, in 2006, there were only 61 astronomers in tertiary institutions in South Africa in the field of astronomy (Whitelock, 2008). There is an urgent need to attract learners to study science at university, which will lead to the next generation of scientists.

This paper reports on a project aimed at designing an experiment that can be executed by high school learners to stimulate their interest in science. By being involved in the experiment, different skills are developed, such as group work, listening skills, mathematical skills and scientific skills. The experiment in this project consisted of assembling a payload and sending it to the stratosphere using a weather balloon. The payload was a Raspberry Pi computer to which various sensors, as well as a GPS and GSM module were connected.

The research question stated for study is: How can an experiment using a stratosphere balloon be used to stimulate secondary school learners' interest in science?

The layout of the paper is as follows: In section 2, the background to the study is presented. An overview of the research methodology is given in section 3. In section 4, the experiment is discussed and in section 5, the results are presented. Conclusions and further work is offered in section 6.

BACKGROUND

The AIAA (2018), the American Institute of Aeronautics and Astronautics, is an institution that provides opportunities, such as career enhancement and employment opportunities for the aerospace community. There are also opportunities for educators and students in the STEM (science, technology, engineering, mathematics) areas. They make use of experiments, such as launching high-altitude weather balloons where they involve school learners in order to expose them to physics concepts and research skills, and in doing so, space exploration is put within reach of learners. This initiative served as an example to follow for this project where a weather balloon is

fitted with a payload consisting of a Raspberry Pi, camera, sensors and a GPS tracking device. The school learners are involved in the launching and retrieval of the balloon in order to give the learners hands-on experience. Another example of where learners participate in experiments to increase science interest is Earth to Sky Calculus (2015). School learners have been launching research balloons to the stratosphere since 2010. Learners have benefitted from this initiative by being more successful at university level than expected, taking into account their small-town background (Bishop, California, population – 5 000).

The specific knowledge that learners may gain while conducting such an experiment is on a variety of levels (AIAA, 2018). The scientific knowledge that the learners acquire in carrying out the experiment is the operation of gases and how it gets the balloon in the air. Which gas does the researcher use to raise the balloon and what are the different forces acting on the balloon? What is the reason why the balloon burst after reaching a specific height? Which formula is used by the researchers to determine how much gas is needed to get the balloon higher in space? What are the different properties that the atmospheric layers have and how to prepare the experiment for these extreme conditions, such as to isolate the payload against very low temperatures? How do the components of the payload work and how do these components function to collect different datasets as the stratospheric balloon moves through the atmospheric layers? What is the basic operation of programming and how is it applied in this project to process all data collected? What is a CME (Coronal Mass Ejection) and how does it affect cosmic rays? How are the different magnitude geomagnetic storms formed and what are their influences on the earth? How are cosmic rays detected and what does this mean for the experiment? How does one plan balloon flights and determine where the balloon will land? How does one interpret the data after the experiment has been performed? From the above, it is clear that exposure to a variety of knowledge areas can be enriching to the learners by taking part in such an experiment. For this project, a secondary school was chosen to engage its learners in the launching of a space balloon thereby broadening their horizons to science as a possible career option and increasing their interest in the STEM subjects.

METHODOLOGY

In this project, an activity was designed in which school learners participated in a space science experiment. A Computer Science honors student planned and created the experiment as part of his studies under the direction of his supervisors. On another level, the project can also be viewed as an experiment where the participation and experiences of the learners in the activity was the aim of the study. According to the Cambridge dictionary (2018), an experiment is “*a test done in order to learn something or to discover if something works or is true*”. In this project, the researchers wanted to discover what the learners would experience by doing the scientific activity. Furthermore, a secondary aim of the experiment was to enable the learners to gain knowledge about the upper atmosphere. Overall, a design science approach was used (Peffer et al., 2014). The payload of the weather balloon was in the form of an artifact that consisted of hardware components that had to be programmed to gather weather and space condition data. The payload data was analyzed using descriptive statistics.

Data from learners regarding their perceptions on their involvement in the balloon experiment was gathered through short questionnaires that were analyzed in order to learn from their experience. A questionnaire was given to the learners before the experiment and another questionnaire was given to them after the experiment. These include knowledge questions and perception questions and whether there is an increase in their interest in science. These questions are listed as follows:

Questions asked before the experiment

1. Do you know the different layers of the atmosphere?
2. Do you know what a Raspberry Pi is?
3. Do you know how a circuit board works?
4. Which layer of the atmosphere is the hottest?
5. Do you know how the GPS component works?
6. Why do you think the balloon elevates?
7. Do you know why the balloon bursts - motivate?
8. How long is a sun cycle?
9. Why do you think we isolate the payload?
10. Do you think plants can survive in the outer layer of the atmosphere?
11. Why do you think we collect the temperature data?
12. Are you interested in science or similar subjects?
13. If you answered yes for the question above, in which field do you want to specialize in and at which university do you want to study?
14. If you answered no what are you going to do?
15. On a scale of 1 to 4, will such an experiment attract you to the study of science?

Questions asked after the experiment

1. Which part of the project did you enjoy the most?
2. Do you want to do more experiments like this one?
3. If you answered yes for the question above, what will you do differently?
4. After conducting this experiment, are you more interested in science?
5. What did you learn after conducting this experiment?
6. With what type of gas is the balloon filled?
7. How does the researcher know where the balloon is?
8. Which part of the experiment interested you the most and would you like to learn about more?
9. Do you know what NASA is?
10. Would you conduct these experiments for a source of income?
11. Are you interested in astronomy or space science?
12. Do you know about the possible jobs in astronomy?
13. If you could study, at which tertiary institution?
14. Are there aspects that prevent you from studying?

EXPERIMENT

The experiment is described in two sections. The payload of the stratosphere balloon is discussed in the first section and the execution of the experiment is discussed in the second section.

Payload

The components of the payload were placed in a Styrofoam container to protect it against the low temperatures.

All data was collected using a Raspberry Pi Zero and then stored on a micro SD card (Akerman, 2016). The micro SD card can then be read using a computer where the data can be analyzed. A special GPS unit was used because normal GPS units stop functioning at an altitude of approximately 24 000 meters (Karol & Lee, 2012). The unit that was used is the uBLOX MAX-M8C Pico, because it can function up to a height of 50 kilometers above sea level, which makes it ideal for the experiment.

The Raspberry Pi Sense HAT was used to collect basic environmental data as the stratospheric balloon moves through the atmospheric layers (Akerman, 2016). The data collected was temperature (inside the payload container), air pressure and humidity. The Sense HAT can also take readings of how fast the artefact moves and keep track of the payload's rotation in three dimensions. Figure 1 shows the GPS module and the Raspberry Pi Sense HAT.

An External Temperature Sensor was placed on the outside of the payload container to monitor the outside temperature as the balloon goes through the atmospheric layers. The sensor is rated for very low temperatures and is waterproof.

A Raspberry Pi camera was used to take photos for the duration of the experiment. The camera was on the inside of the container to protect it against the extremely low temperature, but had a Perspex window through which it could take photos. The camera was programmed to take a photo every five seconds of the flight.



Figure 1: GPS Module (left) and Raspberry Pi Sense HAT (right)

The payload was suspended from a parachute, which was suspended from the balloon. A standard 600-gram weather balloon was used. Once the balloon burst, the parachute would open to slow the descent of the payload.

Execution of the experiment

The balloon flight had to be planned ahead of time to determine the approximate position of where the payload would land depending on the wind conditions of the day. Furthermore, permission had to be obtained from ATNS (Air Traffic Navigation Services) to launch the balloon and while the balloon flight was in progress, ATNS had to be kept up to date of the position of the balloon.

25 learners took part in the execution of the experiment at a high school in the Free State. A pre-test was given to them asking them knowledge questions on scientific issues and relevant hardware topics, as well as their perception on their interest in science. The questions are listed in the previous section.

After the retrieval of the payload, a post-test was given to the learners where knowledge questions, as well as perceptions on their experience in this activity were assessed as shown in section 3.

Figure 2 displays a photo of the learners participating in discussions and the demonstration of the payload and the setup of the components.



Figure 2: Learners with the researcher and teachers

RESULTS

Some of the data that was retrieved and analyzed from the payload is as follows:

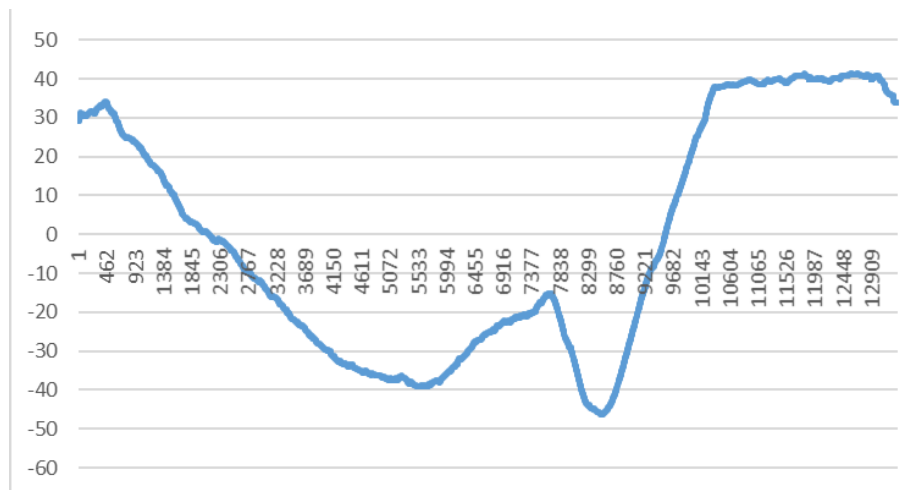


Figure 3: External temperature vs time (seconds)

Figure 3 shows how the temperature changed from launch (30 degrees), going into the air and dropping to approximately minus 46 degrees Celsius. The GPS cut out at about 12 km and started to function again during the descent phase. The position and heights of those times are unavailable and further investigation into this is necessary as the GPS is documented to work up to 50 km. The Sens Hat generated a lot of noise, which must also be rectified. The distance between the launch site and the landing site was 24 km. The Styrofoam container was located by using the GPS.



Figure 4: Photo taken at maximum altitude of approximately 24 km

Figure 4 shows a photo taken by the camera at maximum altitude indicating the area where the balloon was launched. The different layers of the atmosphere are visible.

Data from the questionnaires

From the first questionnaire it emerged that the majority of learners are not interested in science as a subject (64%). Other knowledge-related questions were answered in a diverse way. For example, only 12% of the learners know why the balloon burst in the air. Question 9 (*Why do you think we isolate the payload?*) was answered partially correct by only 32% of the learners. They only thought of getting the data safely back and did not think about the extremely cold temperatures at high altitudes.

From Figure 5 it can be seen that the learners gained an interest in science by taking part in this experiment. 38% of the learners stated that they are interested in science in the first assessment and after taking part in the experiment 68% indicated they are indeed interested in science.



**Figure 5: (Left) Before: Are you interested in sciences or a similar subject?
(Right) After: After conducting this experiment, are you more interested in science?**

Some of the post-test questions results are shown in Table 1. The data was analyzed and coded into categories. It is seen that the majority of the learners enjoyed the launch stage of the balloon the most. Some enjoyed the whole experiment and some enjoyed the specifics of the payload.

The part of the experiment that interested the learners the most was the electronic components and then the balloon itself. Three learners stated that the data gathering phase was the most interesting.

When asked what they would do differently a next time, it is significant that they wanted to go bigger and use other techniques or do more experiments and also send up other items, e.g. plants. The question of what they learned while doing this experiment was put into categories – most of the learners rated either the science aspect or the computing/hardware topic the highest with eight learners each. An interesting issue was that human aspects or feelings emerged from the data, e.g. *“This work is interesting”, “Science is nice”* and *“You must have patience”*. The question concerning their interest in astronomy was answered positively by 48% of the learners. It is important to nurture the interest of these learners so that they will proceed to further studies in the STEM subjects.

Table 5. Results from the post-test

Number of learners	Which part of the activity did you enjoy most?	Number of learners	What would you do differently a next time?
16	Launching of balloon	13	None
3	Information on whole experiment	5	Bigger size balloon
3	How the components/payload work	1	Another technique for locating the balloon
2	The explanation of the experiment	1	Do more experiments
1	Information on Helium gas	1	Send up plants
Number of learners	Which part of the experiment interested you the most and would you like to learn about	Number of learners	What did you learn while conducting this experiment?
7	Electronic components	8	Science
4	Weather balloon	8	Computing/HW
3	Data gathering	4	Human issues
3	Working of the GPS	3	Experiments
2	Atmosphere	1	Flight plan
1	To launch the balloon myself		
1	Programming		
		Number of learners	Are you interested in astronomy?
1	Locating the box	13	No
1	Photos taken by the camera	12	Yes

It is acknowledged that the number of learners is low and that generalizations cannot be made for all learners. However, the concept of using an experiment such as this one is shown to be effective to attract learners’ interest in science.

CONCLUSIONS

In this project, an experiment was designed to create a payload for a space balloon using electronic and programmable components. School learners were engaged in this activity and in the launching of the balloon. The aim was to increase their interest in science as a subject and to let them gain knowledge about the payload and electronic components and the gathering of weather data that was done with the payload.

From the previous discussion, it is evident that the learners enjoyed the launching of the balloon and were very interested in the functioning of the electronic components. The learning experience was very much on science aspects, as well as on computing and the hardware topics. Most of the

learners (68%) indicated that they are more interested in science after being part of this experiment. The research question of how an experiment using a stratosphere balloon can be used to stimulate secondary school learners' interest in science is addressed as a concept with this activity where 25 school learners were involved. However, a greater variety of experiments is needed to stimulate interest in STEM subjects.

For future work, it is envisaged to add a radiation sensor to measure cosmic rays. Furthermore, a radio transmitter can also be used to broadcast position and data to the ground. Regarding the profile of learners, the experiment should be taken to previous model C schools and township schools.

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THE WAVE OF THE FUTURE – MOUNTING SELF-DIRECTED LEARNING SKILLS IN SCIENCE EDUCATION AS A NECESSITY FOR 21st CENTURY EDUCATION

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ABSTRACT: Science and technology are recognized as forces of power in the shaping of the characteristics/futures of learners. Countries are faced with the task of creating for themselves pathways of learning which can lead to the knowledge uprising. Today, teachers need to prepare learners for a world we cannot envisage, and self-directed learning (SDL) has developed an indispensable underpinning for 21st century learners and is reflected as a decisive goal of education. The human race necessities SDL for survival and this basic human potential, knowing how to learn, is a necessity for living in the 21st century. Education in the 21st century is conspicuous with a cumulative requirement to learn innovative skills, abilities and cultivate new understandings where change and transformation is continuous. The science educator cannot only provide learners with information. As knowledge, skills and abilities change, it is essential to teach and demonstrate to learners how to learn. By coaching learners to reflect and in what way they need to learn will empower them with skills necessary to pursue their learning goals as well as life goals. By mounting their skills and abilities to follow their goals, learners will be endowed to transform from inactive receivers of knowledge to vigorous organizers of their own learning. It is therefore my belief that providing both learners and teachers with more accountability, ownership and 21st century skills in their learning, it can result in a meaningful learning experience.

Keywords: Self-directed learning; 21st century education; 21st century skills; responsibility; self-directed learning skills; life goals; science education

INTRODUCTION

Knowledge, skills and abilities change over time and information is developing ever more specialized. Technology is changing how we acquire knowledge and how we function in the learning and working environment. Decision-making, information involvement, cooperation, innovation, meta-cognition, problem and project based skills, communication and self-directedness are crucial in the 21st century (Brookfield & Heimstra, 1991; Mezirow, 1985). Today, success lies in being competent and able to communicate, share and use information, in being self-directed, in being capable to adapt to new demands and changing circumstances in the learning process and in being capable to use technology to create and support new knowledge. To meet this challenge, science education need to be reformed so that learners will be capable to obtain these mentioned skills like creative and critical thinking skills, decision-making skills, collaboration skills, problem and project based skills which they will need to be successful in school, work and life. Carroll (2007), Bybee and Starkweather (2006), Fisher and Frey (2010) and Trilling and Fidel (2009) debate that 21st century learning skills are imperative for attaining the essential transformation within an individual learner to be self-directed in school, work and life (du Toit-Brits, 2015; 2018).

SELF-DIRECTED LEARNING WITHIN 21ST CENTURY EDUCATION

21st century education refers to a new education approach that prepares learners for life in the 21st century. Regardless of technology in learning environments, learners will not learn by themselves (Fisher & Frey, 2010). Teachers in South Africa and all over the world need to focus on meaningful learning where they need to understand how learning takes place and how they can improve learners' ability, and desire, to keep on learning (Knowles, Holton & Swanson, 2015; Trilling et al.,

2009). For teachers and learners to focus on meaningful and transformative learning, the “self” need to be engaged in the learning process that learners can be given the learning opportunity to direct their own learning in science education. And so, personalised learning, namely SDL, is an important constituent in science education for the 21st century education.

A description of self-directed learning

A description of SDL that is well known within this body of scholarship, is that of Knowles (1975). He defines SDL as the “process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes” (Knowles, 1975, p. 18). Even though Long (2002) expresses that there have been numerous descriptions written for SDL, he sees SDL as an individually focused purposive mental development typically accompanied and sustained by behavio[u]ral actions involved in the identification and searching of information (Long, 1988). More directly, Bolhuis (2003:335) explains SDL as “being in command of oneself, moving towards one’s own goals”. In the body of SDL scholarship Knowles’s description is the most encompassing; for that reason, I will predominantly employ his description of SDL for this paper. From the above mentioned description it is clear that having choices and being in control of one’s own learning is unavoidable for SDL to be successful I in the 21st Century.

Merriam and Bierema (2014), Zmuda (2010), Merriam, Caffarella and Baumgartner (2007), (Hiemstra, 2013) and Knowles, (1975) argue that SDL origin in adult education and is imperative for adult education whereas Van Deur (2018), Bolhuis and Voeten (2001), Louws, Meirink, van Veen and van Driel (2017) have argued for the importance of SDL to feature in educating learners. Louws et al. (2017) strongly emphasised that the best way to enhance SDL in learners (in all subjects) is to surround them from a young/early age with SDL activities, a SDL environment and the teaching of SDL skills (Du Toit-Brits, 2015; Trilling et al., 2009). So, it is imperative to understand that aims and objectives for enhancing SDL skills in learners and therefore SDL in science classrooms, skills need to be taught to learners, i.e. motivation, problem solving, project based learning, critical thinking, personal attitude etc. which is embedded within the CAPS policy. Merriam et al. (2014) provide a numeral of explanations of the SDL process, but they also note that a considerable amount of the research on SDL has concentrated on SDL as a personal attribute. In their research, they mention the features/characteristics of a self-directed learner, influenced by Guglielmino’s (1978) Delphi survey of experts, as one who exhibits:

- I. initiative, independence, and persistence in learning;
- II. one who takes responsibility for his or her own learning;
- III. problems as challenges and not as obstacles;
- IV. one who is capable of self-discipline and who is inquisitive;
- V. one who has a desire to learn and to change;
- VI. one who is self-confident;
- VII. one who can organize his or her time;
- VIII. one who can set an appropriate pace for learning;
- IX. one who can develop a plan for the completion of learning work;
- X. one who enjoys and appreciates learning; and
- XI. one who has the tendency to be goal-oriented (Guglielmino, 1978, p. 73; Van Deur, 2018).

All these features/characteristics of a self-directed learner, is important in the teaching of science education. Learners as well as teachers need to be willing to take part in SDL and to be self-directed. Therefore, in this paper, I shall refer to SDL as the willingness, the ability of learners to take control, make choices, and take accountability for their own learning and learning outcomes in Science education.

Why self-directed learning in Science education for the 21st century?

When reading through the above learner characteristics I become aware that these characteristics are critically important due to the explosion of science, information and technology. Louws et al. (2017) debate that the changing world is associated to the digital revolution, where self-directedness and SDL have become vital (Bolhuis, 2003; Bolhuis & Voeten, 2001). Within this changing world, learners should learn to study more independently, preparing them better for higher education, work and life in the 21st century. For this to happen, the science curriculum should underscore 21st century education, namely that the science curriculum is aimed to be learner and problem-centered and that curriculum improvement need to be nontechnical-nonscientific; and that the science curriculum is applied in a way of situational praxis. The Curriculum and Assessment Policy Statement (CAPS) states that science learners should achieve certain skills. The CAPS also inspires skills development, aimed at fostering a relationship between science, society and the environment, the growth and use of science process skills, the application of scientific knowledge, and skills related to scientific processes and thinking. However, the challenge is teachers who resist change and the implementation of the CAPS policy.

Bolhuis (2003) argued that SDL is important within the 21st century because their education need to contribute to a democratic society. The notion of transformation conveyed an awareness of diverse and changed views as well as different habits of mind and life, navigated towards a newly emerging global village (Bolhuis, 2003). A democratic society is thus required and SDL can contribute hereto (Van Deur, 2018). A democratic society with the expectation of developing 21st century skills of learners, as well as SDL capabilities of teachers, demands for collaborative teaching and learning experiences (Darling-Hammond & Bransford, 2005). In agreement with these expectations, the South African Department of Basic Education (2010) also emphasizes the importance of SDL as an educational goal by affirming that the CAPS aims to make sure that learners acquire and apply knowledge and skills in meaningful ways to their lives, by endorsing knowledge in local contexts, although being sensitive to global necessities. The current policy implies a variety of teaching approaches that should be used to fulfill the listed aims. The challenge therefor is the implementation and teaching strategies adopted by teachers on the ground.

Endorsing the prior argument, Carrol (2007) emphasised that classrooms and schools have not changed, even though the empowerment of teachers. Nasri (2017, p. 3) has led a study about teachers' part in endorsing SDL amongst their learners, where it was determined that "SDL requires a transformation from the authoritative role of the [teacher] into the [teacher] as a facilitator of learning because, to promote an active learning approach, [teachers] should acknowledge learners as equal learning partners..." It is therefore important that teachers (science teachers) need to abandon their traditional authoritative starring role by letting and empowering learners to take control and accountability of their own learning. Science teachers need to use real world experiences that can assisted learners' SDL. These real word experiences can be linked to particular science principles establish in the curriculum. Learners thus need to apply these principles that have some real-world significance. Science teachers play a key part in defining the success and accomplishment of any learning attempt. If teachers are not familiar with SDL at the beginning of a project, support for teachers and also support amongst teachers, are crucial. Support to science teachers can be regarding pedagogical understanding of SDL regarding the processes of goal-setting, self-planning, self-monitoring, self-evaluation, and ways to assess students' work. Support can also be given to teachers regarding the interplay between SDL pedagogical knowledge and technological knowledge. Teachers need to be motivated to employ SDL in science education at the beginning of projects and to have a desire to try out the employment of SDL in science education.

It is also important to note that the role of the learner should change from a position of being dependent on the teacher and the learning material to someone who is interested in science, who can link practical work to science and who is intrinsically motivated to study and learn more of science. Hence, science instruction needs to have the aspects of the presence of science content, learner engagement with science content, stressing on learners' responsibility for their own learning, learners' active thinking and student motivation. Learner engagement with science content should embrace epistemologically reliable processes like reasoning, posing of questions, planning and designing experiments, social interaction and collaboration between learners, teacher, content and resources.

The author of this paper contends that science education is not purely about facts acquisition, but a development of inquiry which necessitates learners to assess and reflect on their own thinking and their own learning related to planning, determining, perceiving, exploring data and facts, and scrutinizing evidence. SDL as an instructional strategy offers learners choices and permits learners to identify, articulate, examine, and reformulate problems and elucidations of their own design (van Merriënboer & Sluijsmans, 2009). Therefore, when SDL is employed with support and guidance for learners, it can support learners develop and progress in the inquiry process important to science education.

Thus, in spite of its (SDL) strengths, the implementation of SDL in science education in 21st century education has been limited due to challenges (time, resources and teachers' knowledge on SDL etc.) associated to implementation. Barth debates that numerous educational institutions "are conducting business as usual (lecture, exam, grade) with little or no effort to incorporate the development of skills and attitudes of self-directed learning or to prepare faculty to do so" (as cited in Guglielmino, 2013, p. 5; Nasri, 2017). But the question still remains how can Science teachers empower learners with SDL skills, vital for the 21st Century?

SDL offers learners numerous skills necessary to succeed and blossom in a fast-paced moving society. With the fast growth of information and technology, many professions use and necessitate training programs for approval standard purposes to provide proof that their learners are involved in SDL (Guglielmino, 2013; Nasri, 2017; Guglielmino & Long, 2011; Payne, Rundquist, Harper & Gahimer, 2013). Because learners (children) are inquisitive, they can be more self-directing (Knowles, Holton & Swanson, 2012; Knowles, 1984) and the development of learners' SDL skills can be fostered through inquiry-based learning (Payne et al., 2013). When SDL is employed in the science classroom with support for the learners, there can be evidence of learner comprehension and knowledge retention, engagement, initiative, independence, persistence in learning, inquisitive, development of problem-solving and critical thinking skills, as well as providing learners with the skills and abilities needed to develop into lifelong learners. Promoting self-direction does not mean giving learners complete control and responsibility but rather providing opportunities on a continuum towards growing independence for SDL and to have in place self-directed inventiveness in all communities that strive to empower learners. The goal of implementing SDL in 21st century education isn't content knowledge and information, but wisdom—learning in how to learn, how to understand, and exploring and analysing the purpose of learning (learning thus for personal and social change).

The acquisition of essential SDL skills for 21st century

The 21st century is thus branded by access, networks, digital media, technology and connectivity, which therefore instantaneously demand new learning models and focuses. In a progressive SDL environment, learners ought to continuously be generating innovative ideas and thinking from numerous sources of information – and be undertaking this, be guided by teachers to steer learning in pursuit of self-knowledge, meaning-making and resourcefulness. These changes are powering

globalisation (Trilling & Fidel, 2009) and due to the ever-increasing explosion of information and technology, lifelong SDL is currently a need for survival (Hiemstra, 2013):

- I. personal and professional continued survival of individuals,
- II. continued survival of the world of work, and
- III. continued survival and flourishing of the societies in which individuals live.

In these times of globalization, upcoming of democratic societies, explosion of information and technology, the stimulus for identifying learning needs, taking ownership of learning and life experiences, finding learning resources and completion of learning work and assessing the learning need to come from the individual learner. SDL of individual learners is the construction blocks of the world of work, societies, and nations.

As mentors and science teachers, we are confronted to prepare our learners to be self-directed individuals required by the 21st century (UNESCO, 2009; Guglielmino, 2013; Knowles, 1975). It is our task to employ approaches for mounting these 21st century skills and attitudes (Table 1) that can move education toward SDL. This change necessitates a transformation within our learners as indicated in Table 1:

Table 1: The acquisition of essential SDL skills for science education for the 21st century (Fisher & Frey, 2010; Trilling & Fidel, 2009)

Essential SDL Skills for science education for the 21st Century	
Moving from dependency to independence, autonomous and self-directedness.	Self-direction — adaptability, initiative, individual responsibility, self-advocacy and autonomy.
Moving from devalued to valuable as the individual learner is a rich source of information and linking knowledge to individual learning experiences.	Collaboration and Communication — cooperative resourcing, social skills, building new individual learning experiences from cooperative learning.
Moving from teacher spoken words to linking what the individual learner needs to know to understanding of what is learnt and the application of it.	Research and Information literacy — accessing multiple sources of information for application to learning opportunities and technology.
Moving towards learning materials that are relevant, and to more problem-centered learning than subject- oriented learning.	Critical Thinking — problem solving, analysis and meta-cognition.
Moving from extrinsic to intrinsic motivation.	Creativity and Invention — resourcefulness, innovation, incorporation of thoughts; constructing intrinsic motivation.
Moving from teacher determined toward relevancy of the learning content learned.	

Thus, just as teachers need support in changing to new teaching methods (new paradigm) and attitudes that can cultivate SDL, learners need structures to support them comprehend the motives for the new methods as well as their parts in the new paradigm (Fisher & Frey, 2010; Trilling & Fidel, 2009; Van Deur, 2018).

THE CHALLENGE TO TEACHERS (SCIENCE): CHANGING THE PARADIGM OF TEACHING TO INCORPORATE SDL IN LEARNING ENVIRONMENTS

The path to changing the paradigm is time-consuming. According to Darling-Hammond (2006), teachers affect the individual learners learning and many of our teachers resist the paradigm shifts in

learning proposed by researchers proposing to move learners toward learner-centric learning and 21st century skills development (Carrol, 2007; Louws et al., 2017; Nasri, 2017; Van Deur, 2018). The role of the teacher as a facilitator is to bring a consciousness of the need to know and to offer real experiences where learners learn and discovers for themselves (Holton & Swanson, 2011). It is the opinion of Holton and Swanson (1998) that satisfying the need to comprehend the drive and determination behind the learning experience may result in better planning of the learning experience, increase motivation to learn, and better learning outcomes and results.

The science teacher need to be active, support learners, endorse critical thinking, provide resources, and modeling metacognitive thinking in a SDL environment. In order for the teacher to make available learning opportunities for responsibility and self-direction in learners, the teacher need to change his/her pedagogical role to facilitator, supervisor, resource supporter, motivator, and modeler of SDL. The teacher need also to make informative choices regarding the learning needs of the learner and curricular needs (Knowles et al., 2015). In cooperation, the learner and the teacher need to analyze learning issues that will help learners gain new perspectives and understandings (Merriam & Bierema, 2014). Therefore, teachers ought to have the desire to move and change learners beyond the surface level of knowledge and endorse 21st century skills development. By endorsing 21st century skills development, many benefits can be gained by learners. It is more likely to:

- I. offer significance to the needs of the learner;
- II. grow and mature proficiency with the use of technology;
- III. inspire the development of how to approach and solve problems;
- IV. solve problems collaboratively;
- V. encourage creativity and invention;
- VI. cultivate critical thinking skills; and
- VII. promote self-directed, life-long learners (Nasri, 2017; Louws et al., 2017; Trilling & Fadel, 2009)

To employ SDL in science classrooms to promote the attainment of 21st century skills, science teachers ought to commit themselves to SDL and they ought to submit themselves to changes within their teaching practice. Science teachers therefore play a fundamental role in the development and reformation of learners' conceptions and attitudes towards science. The guidelines as listed below can be followed by the teacher within their self-directed science classroom environment (du Toit-Brits, 2015) to promote the attainment of 21st century skills:

- I. Build a climate supportive of SDL.
- II. Provide learners more control and accountability to make sure that they are motivated for and engaged in the learning activities and projects.
- III. Making learning significant so that it can foster SDL skills.
- IV. Encouraging self-awareness of learning among learners.
- V. Teachers need to be a self-directed learner themselves and a self-directed agent of SDL.
- VI. Create a collaborative SDL community that supports learners' learning challenges and challenge thinking.
- VII. Develop and provide active and collaborative SDL activities.
- VIII. Embed the need to know.
- IX. Provide learners with choices.
- X. Deliver learning opportunities for reflection
- XI. Promote critical thinking.
- XII. Provide meaningful feedback.
- XIII. Teachers need to expose learners to new possibilities for self-fulfillment, and
- XIV. Teachers ought to support learners to elucidate their own learning aspirations.

Though, what is required is a transformation/change in the thoughts of both the learner and the teacher and this could empower learners to take complete ownership of the learning process through critical and reflective thinking. Methods of facilitating the internalisation of students' regulation of their behaviour and thus optimising their motivation and interest ought to be built into all science activities in classes.

WRAPPING UP

"Learning is a lifelong journey and, as on most journeys, it is important to have a destination in mind and a reliable means to get there" (Trilling & Fadel, 2009:95). The purpose for learners in the 21st century is to be prepared for and competitive in this global economy and to be lifelong self-directed learners (Knowles et al., 2015). The fundamental premise of this paper is that SDL are critical to promote the development of necessary skills within the science classroom for learners' success in their journey towards the 21st century (Holton & Swanson, 2011). As Hatcher revealed, SDL has become the "Wave of the future" where "by 2020, all learning will be based on the principles of self-directed learning" (as cited in Kerka, 1999, p. 4).

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EXPLORING SENIOR PHASE NATURAL SCIENCES TEACHERS' PERCEPTIONS AND CHALLENGES IN THE IMPLEMENTATION OF SELECTED ELEMENTS OF THE CAPS CURRICULUM: A CASE STUDY

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ABSTRACT: This study reports on senior phase Natural Sciences teachers' perceptions and challenges in the implementation of the CAPS curriculum in one district of the North West province. Envisaged teachers' approaches to curriculum components such as content presentation and assessment have had to be altered in order to suit the current CAPS curriculum. A general model of receptivity to planned system-wide educational change proposed by Waugh and Punch (1987) provided the conceptual framework for this study. The study was purely qualitative, thus employed an exploratory case study approach. In this case study, 10 teachers were purposively sampled, one from each school, from 73 schools in the district. Purposive sampling was adopted to identify participants and research sites for the study. Data was generated through interviews, classroom observations and document analysis. Data gathered were thematically analysed using an analytical tool adapted from Attride-Stirling (2001) known as Thematic Networks analytical tool. Results of the study demonstrate that a number of challenges in the implementation of selected elements of CAPS is still a thorn in the flesh for these curriculum implementers. Recommendations such as newly appointed teachers needing motivation and guidance, to get immersed into CAPS curriculum and further research are suggested.

Keywords: Curriculum reform; curriculum implementation; natural science teachers; perceptions

INTRODUCTION

The South African education system has undergone a lot of curriculum changes since the dawn of democracy in 1994; but it has not yet delivered the desired outcomes (Maimela, 2015). Curriculum reform initiatives in South Africa reflect a paradigm shift from a teacher- dominated to a learner-centred approach (Ramnarain, 2014). For many teachers, the shifts, as indicated by Dudu (2014), have put them through a number of challenges. For example, the shift from the Revised National Curriculum Statement (RNCS) to Curriculum Assessment Policy Statement (CAPS) in South Africa meant a significant change in teacher roles. The envisaged teachers' approaches to curriculum components such as content presentation and assessment have had to be altered in order to suit the curriculum at hand, which is CAPS. In order for these teachers to fit in well with the demands of the changes and execute their tasks as required, a great deal of empowerment on the part of teachers is required for changes of this magnitude (Ramnarain & Schuster, 2014), and these are difficult to make without support and guidance. This paper which is part of a bigger study reports on perceptions and challenges of senior phase Natural Sciences teachers' initially solicited before the empowerment intervention was undertaken.

Background to the study

South Africa like many countries over the last two decades have made significant efforts to implement curriculum reform. The reforms have been well-designed with valuable aims. According to Park and Sung (2013), implementation in many cases has resulted in less than desirable outcomes, and well-intentioned curricular reforms were never translated into classroom reality. Kirk and McDonald (2001) believe much research indicate that teachers are the key to curriculum reform success. This is a notion which rarely finds objection in academia. A change in curriculum therefore necessitates a change of the function of the teacher (van der Nest, 2012:5). Teachers' knowledge,

beliefs and perceptions play a fundamental role in the effective implementation of reforms (Park & Sung, 2013). Change is a subjective process in which individual teachers construct personal meanings from the changes they experience (Fullan, 2007). Park and Sung further argue that expecting teachers to implement the curriculum faithfully in a way intended by developers would be wrong. One of the reasons which this study subscribes to is that, teachers formulate their own meanings and perceptions when reforms are introduced to them. Teachers' perceptions can be thought of as their perspective on how one engages in pedagogical practice (Park & Sung, 2013). Understanding what teachers perceive as the purpose of curricular reform is crucial for its successful implementation becomes imperative. Crucial lessons can be learned by educational authorities around the world regarding the possible flaws that might arise in an erroneously implemented education policy through the lenses of this paper. Quite a handful of articles have been crafted regarding the CAPS curriculum, for example, on teachers' experiences on the implementation of the CAPS curriculum as reported by Maharajh, Nkosi, and Mkhize (2017), but little has been written about teachers' perceptions when implementing the CAPS curriculum.

RESEARCH QUESTIONS

Three questions which the study focuses on are: (i) what are senior phase Natural Sciences teachers' perceptions of selected elements of the CAPS curriculum? (ii) What challenges are faced by senior phase Natural Sciences teachers when teaching and assessing from CAPS curriculum? (iii) How can the perceptions and challenges be addressed?

CONCEPTUAL FRAMEWORK

A general model of receptivity to planned system-wide educational change proposed by Waugh and Punch (1987) where the change is planned and implemented in a centrally controlled educational system involving teachers in their classrooms provided the conceptual framework for this study. The model is only part of a more complex model which was constructed to explain teachers' receptivity and it is set out in a linear form so that some simple relationships can be tested. Waugh (2000) alludes teacher receptivity is proposed to consist of four first-order aspects, operationally defined by a number of second-order aspects to the teachers. These are: characteristics of the change (comparison with the previous system and practicality in teacher's classroom), managing the change at school (alleviation of concerns, learning about the change and participation in decisions at the teacher's school), value for the teacher (personal cost appraisal, collaboration with other teachers and opportunities for teacher improvement) and teacher perceived value for learners. In this study, these characteristics were linked to the adapted organising concepts from the thematic networks proposed by Attride-Stirling (2001). The four organising constructs in this study are teachers' curriculum knowledge, instructional knowledge, teachers' subject matter knowledge and resources. From these four organising concepts, eight sub-concepts namely: specific aims, assessment, suggested activities, planning, preparation and presentation, content, process skills, time allocation and learning teaching support material (LTSM) were derived and are discussed. The 8 sub-concepts are the elements of CAPS that were observed during the lesson. Results are presented using these sub-concepts.

METHODOLOGY

The study was purely qualitative, thus employed exploratory case study approach. An exploratory case study was adopted, which according to Basit (2010), supports the production of detailed accounts and deeper consideration of actions, experiences and perceptions.

Sample

The sample consisted of 10 teachers from the rural schools of the rural province; namely North West. They were purposively sampled, one from each school, amongst the 73 schools in the district. Purposive sampling was adopted to identify participants and research sites for the study. The selection was influenced by their information-rich responses of the questionnaires. Convenience sampling was also evoked in the sampling as those teachers not further than 75km from the researchers' workplace were selected. As this is part of a bigger study, the 10 teachers had participated in a preliminary study where they had completed a questionnaire soliciting their perceptions on the implementation of CAPS curriculum. Teachers were assigned pseudonyms 'Teacher 1', 'Teacher 2' until 'Teacher 10'. The sample was purposively selected from one district of the North-West province of South Africa where the bigger study was focused. Purposive sampling is a non-probability sampling method whereby only those teachers teaching senior phase Natural Sciences were sampled.

Research methods

In order to capture the lived experiences, perspectives and knowledge generated by the 10 teachers – 'Teacher 1' to 'Teacher 10', - classroom observations and semi-structured interviews as 'extended conversations' (Holland & Ramazanoglu, 1995) were organised. Teachers were observed teaching their senior phase Natural Sciences classes once and immediately a follow-up interview was arranged. Classroom observation focused on teachers' content knowledge, their classroom practices and their pedagogic content knowledge when implementing CAPS curriculum. The interviews zoomed on the perceptions the teachers harboured during the teaching and learning process in selected elements of the CAPS curriculum. As the teachers were observed teaching some challenges would illuminate themselves whilst teachers elaborate on more challenges during the interview process. A discussion with teachers ensued on how the noted negative perceptions and challenges could be addressed.

Data Analysis

Data gathered were thematically analysed using an analytical tool adapted from Attride-Stirling (2001) known as Thematic Networks analytical tool. This helped organise data into global, organising and basic themes whilst also assisting in the development of several core generalisations. Figure 1 shows how the tool was adapted with themes annotated according to this study data. Lincoln and Guba's (1985) concept of trustworthiness (credibility and confirmability) was used to strengthen and enhance the quality of the findings.

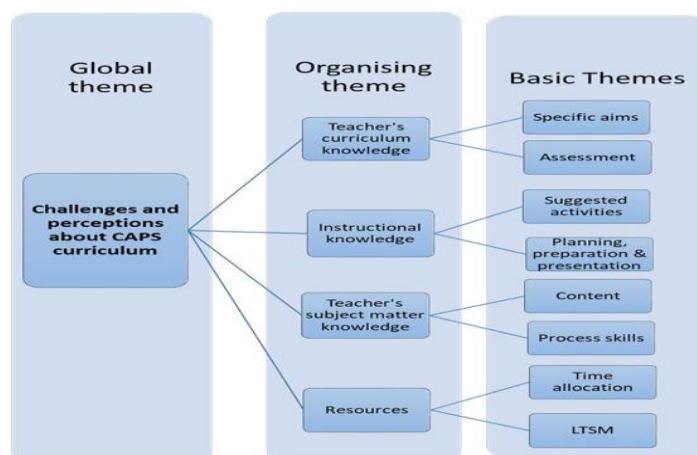


Figure 1: Thematic Networks: Analytical tool for qualitative research adapted for this study from Attride-Stirling (2001)

Results of the study demonstrate the effort these four teachers put in to establish a 'working' strategy of teaching that resulted in improvement and sustained learner performance in Life Sciences and Physical Sciences.

RESULTS AND DISCUSSION

In this section, results are presented based on themes around the four organising constructs (organising themes) which are: resources (time allocation and LTSM); teachers' subject matter knowledge (content and process skills); teachers' curriculum knowledge (specific aims and assessment) and instructional knowledge (suggested activities and planning, preparation and presentation).

First, results related to the construct resources are presented. In half of the 10 classes observed, textbooks and the chalk board were the most used resources utilised mainly through the teacher-talk traditional approach. In two schools, textbooks were shared and in one school, copies of the periodic table from another textbook (teacher's copy) were distributed to learners for use during the lesson. This was categorised as a negative aspect observed in this study. There were also some positive observations made, for instance, in three schools each learner had a textbook; hand-outs from a different source were made for the learners by the teachers; apparatus and some chemicals were used by the teachers for demonstration purposes during the teaching and learning process which was what the school could afford. During interviews, Teacher 7 was asked the following question: kindly describe to me the status of textbooks and other required resources at this school? The teacher responded was: "We don't have resources mmmm, we order books in school but they never arrive, like Platinum textbook we ordered it last year and came this year and only few came. It's surprising because you order with the number of learners but only few books are delivered. So it is a great challenge because when you give learners work they use that as an excuse, but I always tell them that if you don't have a book try to do work here at school before you go home, yeah". Six other teachers gave almost similar responses. Of the 10 teachers only three responded positively regarding resources. Teachers 2, 3 and 6 responded; "we have enough textbooks but not enough apparatus", "we have enough textbooks for the learners. LTSM we have no shortage" and "learners have textbooks, and maybe if we do not have the apparatus, that's where now we begin to improvise because it is now necessary. But with textbook we have them available" respectively. Pertaining to time allocation, most lessons ranged between 40 minutes and 55 minutes and responses were a mixed bag. Some teachers reckoned the time suffices whilst others believed it was not enough. Teacher 9 whose periods are 45 minutes had this to say, "I do not think this is enough time, as there is a lot to do with our crowded classes". This also accords with Maharajh et al.'s (2016) observations, which showed that resources are a problem in most South African schools.

Secondly, regarding teachers' subject matter knowledge (content and process skills), the question asked to the teachers solicited what they found difficult in the teaching and learning about the strand, Matter and Materials which they were dealing with in the term. Teachers were asked if they encountered any challenges regarding, content, learners learning and their content delivery. Teacher 10 had this to say: "The standard for this curriculum is really high because you check we are talking about compounds, we are talking about components they are the very same definition you are going to get in grade 12, like you can ask a learner from grade 12 and ask him or her what is an element but has been taught from grade 7 & 8, but the standard is very high for this learners." Teacher 6 said: "*some topics are difficult for me. They are related to Physical Sciences, and I did Life Science and Geography.*" Six other teachers related the same sentiments. However, Teacher 4 had a different story to tell: "With me I find nothing difficult to teach about the strand, but the learners lack involvement in learning in class generally, and depend on the teacher or some other learners that are involved in learning. Some other learners want to just write and write even when they do not understand." Classroom observation confirmed what the teachers said during interviews.

Pertaining to process skills, questioning was around how the teachers imparted science process skills in a topic or lesson that you teach. Probing was on how the teachers assessed learners to ensure that they were able to grasp the science process skills that they imparted during the lesson. Teacher 6 responded: "I usually impart process skills when we do aaamm...for example experiments...all those process skills like how to handle the apparatus, and like that. Aaamm...the process skills help the learners to actively participate during the lesson. They help the learners to take part, yeah .." Six other teachers reiterated similar responses. The teachers did know much about the process skills themselves. Unlike the other seven teachers, Teacher 10 responses regarding questions pertaining to process skills were satisfactory. This is how Teacher 10 responded: "Process skills assist me to build the learners knowledge on skills required. When they go to grade 10, they must be at that level. I give each learner freedom to prepare something about the topic briefly and stand in front of the class and speak. So that is a skill, communication. They sometimes have to demonstrate some simple experiment to show that they can follow instructions." This finding confirms Van der Nest's (2017) findings which showed teachers understand process skills differently.

Regarding teachers' curriculum knowledge (specific aims and assessment) interesting responses were given. Questions hinged on how teachers incorporated Specific Aims in their lesson planning. Teacher 5 responded: "What I do, I look at the subject matter that I have to prepare then I look at the specific aims and try to find the example that are related to everyday life experience so that it become easy for them to connect what we learn in class to the rest of the environment. For an example rusting is a reaction of metals with oxygen. They know that from home, leaving steel wool exposed to air after washing the dishes". The follow up question was on how teachers then plan the assessment related to the specific aims that they would have used. Teacher 5 responded: "I look at the chapter that I have covered and the specific aims covered then I prepare an assessment that will test them on that. So every little bit we cover I go right away into that and test to see if they understood." This except to a great extent shows how some teachers linked aims to assessment. The single lesson observed corroborates this regarding what Teacher 5 did. Regarding assessment, when asked, how do you manage to adhere to assessment requirements of CAPS? Teacher 4 responded, "Amm, things like investigations, assignments and projects, I start off by explaining to them like what is needed from them and to do it. And also things like terms in those activities like your hypothesis, aims and stuff like that, and then I start by giving them a week or more to do those so that they can correct and go back to fix them." Seven of the teachers referred to formal tasks, writing a test under supervision, without giving reference. This also accords with Park, M. & Sung's (2013) observations, which showed assessment and curriculum interpretation is not an easy process to be implemented by Korean teachers.

The last construct relates to instructional knowledge (suggested activities and planning, preparation and presentation). The question guiding this construct was: How do you use the CAPS document or textbook to plan and prepare your lessons? Teacher 2 gave an interesting answer, "Because I'm new in GET, I first have to see what is suggested we do, but still feel it's vague because I come from FET and I still don't know how much I must teach the learners. Must I do more or little??? I spend more time teaching in detail. So I use CAPS to check content and to see the assessment standard. From there just textbook." However, Teacher 8 explained it differently, "I take my topics, specific aims and process skills from CAPS document then I use the textbooks, that's how I use CAPS to plan." Teacher 4 explained, "Yeah I look into the document for the topic, find suggested activities and find any suggested way of going about teaching the topic." When asked, how do you use suggested activities in the teaching and learning of NS? Teacher 3 responded: "I use them to pick experiments relevant for the topic and materials suggested." As can be seen from the responses, teachers plan and prepare differently. However, most of the teachers present the content the same way.

In answering the questions: (i) What are senior phase Natural Science teachers' perceptions of selected elements of the CAPS curriculum? (ii) What challenges are faced by senior phase Natural Sciences teachers when teaching and assessing from CAPS curriculum? (iii) How can teachers' perceptions of selected elements of CAPS curriculum and their classroom challenges be addressed? An inference can be made from the teachers' responses to questions posed and recollecting some events which took place during the teaching and learning process during classroom observation, which shows that a plethora of challenges confront the teachers on daily basis and more support is needed if the goals of curriculum reform are to be met.

CONCLUSIONS AND RECOMMENDATIONS

From the results presented and discussed, the curriculum reforms were needed in South Africa so as to place the education system at par with that of the rest of the world. However, lack of resources still hampers the progress of this reform. Though challenges reported in this paper did bedevil other countries which have also gone through curriculum change, it is problematic in South Africa. The implementation of CAPS has had a myriad of challenges in schools. Currently, the implementation of CAPS is a difficult task. The literature and the data gathered through the interviews and classroom observations have attested to this enormous difficulty. Proper training of teachers is needed, on-going support from the Department of Basic Education is needed and the provision of resources is essential in ensuring smooth curriculum implementation. Curriculum change in South Africa is a dynamic and challenging task as argued by this paper. There are gaps that need further research and as mentioned earlier, having solicited the perceptions and challenges, the bigger study now moves to implement an intervention to address these challenges. For instance, it emerged that the provision of Learning and Teaching Support Material needs to be strengthened, and augmented in order to improve the implementation of CAPS. Necessary resources must be provided in order to ensure effective curriculum implementation.

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THE AFFECTIVE AFFORDANCES OF FRUGAL SCIENCE (USING FOLDSCOPIES) DURING A LIFE SCIENCES WATER QUALITY PRACTICAL

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ABSTRACT: Manu Prakash said, “It’s important to bring open-ended tools for discovery to a broad spectrum of users without dumbing down the tools.” Scientific equipment in the school laboratory is often very expensive. ‘Frugal science’ is a trend in education which researches, develops and introduces economical quality scientific resources to developing countries. In South Africa, many underprivileged schools lack quality practical resources to perform simple tasks, such as microscopy. Furthermore, the lack of laboratory investigations could lead to learners not enjoying Life Sciences. As part of an indigenous knowledge intervention hosted by the North-West University, teachers were provided with the \$1 Foldsopes (paper microscopes) to utilize in their classrooms. This paper provides views of Life Sciences learners and teacher experiences of using Foldsopes in the Life Sciences classroom during a practical. The paper illuminates how such problem-based approaches could enhance affective outcomes. This generic qualitative focuses on teachers engaging in classroom action research (CAR), in investigating the affordances of Foldsopes. Data was collected using observations, teacher and learner reflections, photographs and personal interviews. Engeström’s third-generation cultural-historical activity theory (CHAT) was used as a research lens, in order to identify factors which promote or inhibit the use of Foldsopes in the Life Sciences classroom.

KEYWORDS: Frugal science; Foldsopes; pedagogical content knowledge; classroom action research; teacher professional development; self-directed learning and affective domain

INTRODUCTION AND PROBLEM STATEMENT

South African mathematics and science education is ranked 128 out of 137 countries, according to the World Economic Forum’s competitive index for 2017 to 2018 (Schwab, 2018). One of the reasons for South Africa’s dismal performance, is the marginalization of the affective domain (De Beer, 2016). Life Sciences teachers often experience that some learners do not enjoy, engage and academically prosper in Life Sciences as a subject (Hidi & Harackiewicz, 2000). Many teachers still use content-based, conventional, transmission mode teaching methods such as chalk and talk (Riga, Winterbottom, Harris, & Newby, 2017), which does not favour ‘out of the box thinking’, autonomous learning (Farahani, 2014) or affective outcomes.

Inquiry-based (heuristic) methods is not a new approach to teaching Life Sciences (Riga et al., 2017). Heuristic methods allow teachers and learners to have a sense of discovery and enhance their own sense of learning (becoming a self-directed learner). The scientific methods and skills cannot be taught using transmission mode teaching, but rather hands-on practical methods and self-discovery. Many teachers neglect using practical based teaching or problem-based learning (PBL) as well as cooperative strategies (Jacobs, de beer, & Petersen, 2016) because teachers feel they may be taken out of their comfort zones. Furthermore, some teachers do not have a sound understanding of the nature of science (Ogunniyi, 2004). Teachers may also avoid problem-based learning as they are not confident or comfortable in conducting hands-on practical sessions with learners (Josef De Beer & Petersen, 2016). Many studies have been done to indicate that teachers avoid problem-based

learning and cooperative learning due to a full curriculum and time constraints (Cronje, 2015; de Beer, 2017).

Another issue in South African education is the lack of quality resources including practical equipment in the Life Sciences classroom (Cronje, 2015; Jacobs, 2015; Pretorius, 2015). Consequently, there is a need for quality 'shoestring approaches' (De Beer & Petersen, 2016) or, 'frugal science' (Ahuja, 2014). Teacher agency requires constructive thought processing and improvising various approaches to reach the aims of the content in the Life Sciences curriculum. Therefore, during the indigenous knowledge interventions held by the North-West University, teachers were introduced to Foldscopes, a microscope which was developed by Stanford University (Cybulski, Clements, & Prakash, 2014) and were invited to develop their own practical activities, hence the importance of exposing teachers to classroom action research (CAR).

AIM AND RESEARCH QUESTIONS

Aim

The aim of this paper is to report on the affordances of the implementation of Foldscopes during two teachers' classroom action research (CAR).

Research questions

- What are the affordances of utilizing Foldscope microscopes in promoting affective outcomes in the Life Sciences classroom?
- What are teachers' experiences of engaging in classroom action research (CAR) on Foldscopes, and what are the affective affordances of such CAR?

LITERATURE REVIEW

Frugal science and Foldscopes

Many South African schools do not have the privilege of quality school resources (Mampane & Bouwer, 2011), including laboratory equipment for practical work in the Life Sciences classroom. 'Frugal science' is a concept in education which introduces cheap, accessible scientific educational tools within developing countries (Ahuja, 2014). The Foldscope is a cheap optical paper microscope which was designed and developed by Manu Prakash and his students at the Stanford University School of Medicine (Ahuja, 2014). The paper Foldscope can magnify up to 2000X, which is more than the normal light (compound) microscope (400X), and this allows for greater detail when viewing unicellular organisms. The Foldscope is also portable and can be used for fieldwork anywhere in nature, without electricity. Teachers can easily design hands-on activities (classroom action research) using the Foldscope as part of the infusing of indigenous knowledge in the Life Sciences curriculum.

Classroom action research (CAR)

Gravett and De Beer (2015: 344) explain classroom action research (CAR) as "*more data-based and systematic than reflection, but less formal and controlled than traditional educational research.*" During the intervention on infusing indigenous knowledge in the Life Sciences classroom, teachers were trained in engaging in classroom action research (CAR). This CAR centered around the use of Foldscopes in the classroom, and its affordances.

There are various steps which should be followed during the CAR cycle. Firstly, teachers are required to identify a problem in the classroom. In this case, the problem that the two teachers (who engaged in CAR) identified is the lack of curiosity and interest among learners (Pretorius et al., 2014) during the topic of Ecology. Secondly, teachers are required to plan their research.

In this case, the two teachers planned a water quality project using the Foldscopes. Ethical considerations were vital, and however, the teachers, being employees at the school, had to obtain consent from both learners', parents and school principal.

Thirdly, the teacher has to take action and collect data. The water quality activity was conducted, and learners completed the practical handout, which was then analyzed. The data was transcribed and coded by the researcher to determine what the affordances of Foldscopes are.

Reflection cannot be excluded from CAR, and teachers must continually reflect during the lesson as well as during the entire CAR. These reflections were also used as data in this paper. Such reflection could assist teachers to become more self-directed learners (SDL) (Knowles, 1975) and agents of change (Van der Heijden, Geldens, Beijaard, & Popeijus, 2015).

Affective domain

The affective domain as a learning domain has been neglected by the education community (Garritz, 2010). The cognitive domain is centralized in education, yet the affective domain (values and attitudes, such as perseverance, tolerance, etc.) is a driver for cognitive development. Research in neuroscience (Dubinsky, Roehrig, & Varma, 2013) shows that experiences with an emotional flavour are more likely to be committed to memory.

The affective domain includes teacher and learner perceptions, interests, attitudes, values and emotions (Birbeck & Andre, 2009; Clark & Price, 2016). Krathwohl's taxonomy was used as an intermediary theory in order to see if any affective learning took place during the water practical using the Foldscopes. There are five affective categories which indicates internalization. These include receiving, responding, valuing, organization and characterization by a value complex (Krathwohl, 1964; Lynch, Russell, Evans, & Sutterer, 2009). The focus of this paper is to investigate affective gains among learners and teachers, who respectively engaged with Foldscopes and CAR.

RESEARCH DESIGN, RESEARCH METHOD AND THEORETICAL FRAMEWORK

Research design and methods

This paper stems from a larger NRF-funded design-based research project, which followed a generic qualitative approach (Creswell, 2007; Merriam & Tisdell, 2015) and reflect teachers' experiences of engaging in classroom action research (CAR) as well as learners' participation in using the Foldscopes in a water quality study.

As part of the NWU indigenous knowledge intervention, teachers received Foldscopes to use in their classroom. After the intervention, two enthusiastic Life Sciences teachers were selected, to observe their CAR activities in their Life Sciences classrooms. The activity was using the Foldscopes to assess the quality of water in South Africa (on a very small scale).

The Foldscope activity was developed by one of the participating teachers, using the CAR cycle as explained earlier. The Foldscope activity consisted of two components.

Firstly, learners had to conduct fieldwork, whereby they had to collect a water sample from a dam or river close to their home, observe their surroundings and test the pH and the temperature of the water. The second part of the learning opportunity included the Foldscopes. Learners had to further test the water samples in the classroom (practicing their laboratory/practical skills), including testing pH, temperature and the ammonia test. Learners had to fold the Foldscopes carefully following the instructions provided. After folding the Foldscope learners were required to make prepared slides from their water samples in order to view unicellular or multicellular organisms. Finally, learners had to complete the practical write-up which included writing reflections.

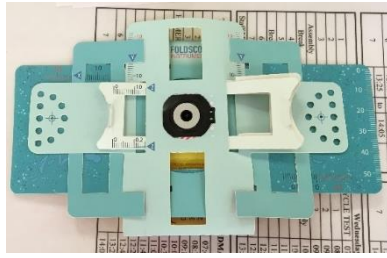


Figure 1: Completed Foldscope done by one of the learners

Ethical considerations

Ethical clearance has been provided by the Faculty of Education's ethics committee. Consent and permission forms were handed out to the teachers, learners (and their parents) involved in the CAR.

Data analysis

All the data which has been transcribed was analyzed to make sense of the data from the interviews and reflections. Saldaña (2015) code-to-theory was used to distil emerging themes. Emotion coding was used in this paper as it investigated the affective learning of teachers and learners, using the Foldscopes. Emotions are part of the teachers' and learners' worldview and provide a variety of perspectives (Saldaña, 2015).

Validity, reliability and trustworthiness

Validity is a facet in qualitative research which ensures that the researcher is measuring what is actually being measured (Thyer, 2001). Member checking was used, and generated data was taken back to the participants to ensure what was written reflected their realities.

Theoretical framework

This study employed social constructivism as the theoretical orientation. This social constructivist parlance allowed the researcher to make sense of learner and teacher experiences during the water quality investigation (Seimears, Graves, Schroyer, & Staver, 2012). Social constructivism has its roots in the developmental theory and the Zone of Proximal Development (ZPD) of Vygotsky (Vygotsky, 1978). Furthermore, activity theory underpins this paper, and this assisted with further analyzing the data. Engeström's third-generation cultural historical activity theory (CHAT) was used (Engeström, 2009) on an interpersonal plane (see paragraph 5.6).

FINDINGS

The following themes emerged from the analyzing the data of the Foldscope activity.

Theme 1: Some learners were frustrated that no 'quick-fix' guidelines were provided for the Foldscope microscopy activity, and that they had to devise own experimental designs.

Our education system values 'correct answers', and learners often get used to learning activities which are clearly structured, and where they can follow 'recipes', without having to learn through trial-and-error, or where they have to show agency (De Beer and Petersen, 2016). This was clearly indicated in the data. Learner (L) 33 said *"it took a while for me to gain trust in myself, as I didn't want to make a mistake."* L1 stated *"it was difficult because the instructions weren't specific"*, and L2 commented *"it was extremely difficult to fold the microscope as the instructions were not very clear and many of the parts looked similar to each other."* Data from this research shows that learners are used to being 'spoon-fed' because it is very difficult for them to follow instructions on their own.

Theme 2: Learners enjoyed the overall experience of folding the Foldscope, and indicated that it was fun, interactive but also challenging.

The data shows contradicting expressions from the learners. Learners found the activity very difficult yet rewarding. L7 indicated that *“the folding of the Foldscope microscope was very interesting and challenging,”* and L44 said *“it pushed me out of my comfort zone as normally I do not build things or enjoy making things, but I really enjoyed building the Foldscope.”* Taking learners out of their comfort zones, created a sense of dissonance, whereby learners engaging with the learning material, found it challenging at first, yet satisfying and enjoyable at the end. L27 said *“the folding of the Foldscope microscope was a challenging, and yet rewarding task – at times I truly struggled to interpret the instructions that were provided on the instruction manual and thus the folding was quite tricky at stages – and yet, it was exhilarating at the same time, every time I folded a piece of the microscope. During certain stages of the folding process, I experienced irritation and agitation due to the fact that I could not achieve the desired outcome / fold the different pieces together in the manner that was depicted on the instruction leaflet.”*

Not only was the Foldscope activity challenging for the learners, but data also showed that learners were fearful to complete this activity and easily gave up. Teacher (T) 2 indicated *“those who persisted did see things, but some gave up.”* L55 indicated the following: *“I was a bit scared that I was going to tear it but if you work carefully you won’t.”* This showed some anxiety in the classroom, thus indicating that teachers don’t always give learners hands-on activities to stretch themselves.

Theme 3: The affective domain was addressed during this hands-on practical.

Learners indicated that it was a simulating and fun task, in which they could enter into *homo ludens* mode, which means the playing human (pedagogy of play) (Huizinga, 1955 as cited in Jautse, Thambe & de Beer, 2016). L2, L5, L9, L12, L28, L33, L35, L40 and L41 indicated that the Foldscope activity was *“fun”*. L42 said *“it allowed us to let loose, be creative and embrace our inner child.”* This shows that learners really enjoyed the hands-on Foldscope activity.

Data clearly showed that the affective domain was evident in this learning opportunity. Learners showed respect for each other and engaged in collaborative learning. L7 said *“I found myself asking for help whilst constructing it more than once, my classmates were very helpful and we all tried to help each other if need be.”* L28 mentioned that *“you feel like a proper biologist”*.

Theme 4: Learners show an appreciation for the role of Life Sciences in Society (CAPS- AIM 3).

The curriculum and assessment policy statement (CAPS) includes three aims, one being appreciating and understanding the history, importance and application of Life Sciences in society (Department of Basic Education, 2011:1). The data indicates that learners showed appreciation of the role of science in society. L5 reflected, *“the Foldscope was a valuable tool as it brings microscopes to everyone at a very cheap price, which will end up exposing more people to biology and increase knowledge and learning within schools, the overall prac gave me some insight into how people cause pollution, and how rural people can investigate the quality of their water.”* Furthermore, L9 indicates *“it gives me great pride to know that under privileged children will soon feel the joy and curiosity one feels when they look down a microscope.”* L15 argued that, *“very often people assume water is safe to drink because the water looks clear which indicates there’s nothing in the water. Through the use of the Foldscope it was found that there is in fact many organisms that inhabit the water.”* Learners have indicated that there is a lack of scientific literacy in the community, but with the use of the Foldscope, more people will become aware of scientific reasoning.

Theme 5: Teacher as a reflective practitioner, researcher and self-directed learner using CAR.

The teachers’ reflections indicate that designing and implementing problem-based activities are *‘daunting’* for them, as also shown by other studies (De Beer & Petersen, 2016). The Foldscope is

also a new tool that teachers were not familiar with and did not really know what to expect, and they therefore had to acquire a variety of new skills.

T1 conducted the Foldscope activity with two classes. The first lesson was challenging as the teacher realized that the instructions were difficult for the learners to follow. Therefore, the teacher reflected *“how can I improve my next lesson?”* The teacher found videos that show step by step instructions for the learners to follow, thus the second lesson went much better. L9 said *“the instructions on the paper in the package was very difficult to follow and was unclear, but the video was helpful.”*



Figure 2: Life Sciences teacher using the Foldscope during classroom action research (CAR)

T2 indicated that it takes a lot of time to perfect the technique, thus losing valuable teaching time. Again, time is a major factor in the Life Sciences classroom, and many teachers avoid doing practicals because of this. T2 indicated that there is value to doing hands-on activities in the Life Sciences classroom to develop fine-motor skills because *“children aren’t accustomed to paper model building and struggles with instructions.”* Both teachers reflected that the CAR assisted them to become more critical reflective practitioners.

Looking at the data through a CHAT lens

CHAT is a useful lens to analyze data, to provide a ‘rich description’. In figure 3 focus is placed on the Life Sciences classroom (where Foldscopes were used), by identifying two interdependent activity systems (Mentz & De Beer, 2017). Although the teacher is teaching in a classroom setting, it does not necessarily mean that the learner is learning (Brown, 2003). The two activity systems in figure 3 are therefore the learner as subject, engaging in learning activities (diagram on the right) and the teacher as subject facilitating the Foldscope learning activity (diagram on the left). The use of CHAT in this rather unconventional way (Mentz & De Beer, 2017) allowed the researcher to see what transfer of affective outcomes took place in the classroom using Foldscopes. The different nodes in the third-generation activity system include the subject (S), object (O), tools (T), community (C), rules (R) and division of labour (D) (Engeström, 2000). The tools that the teacher and learners utilized during the CAR include the Foldscopes, educational equipment and laboratory equipment. The activity system was guided by rules, namely the Nature of Science (NOS) (the learners completed the practical activity that followed the scientific method), the Subject Assessment Guidelines (SAGS) (IEB, 2018) or Curriculum Assessment Policy Statement (CAPS) (Department of Basic Education, 2011), as well as the problem-based learning rules. The community included the principal, parents, teachers and learners. The division of labour in triangle 1 include the teacher as a facilitator of learning, critical reflective practitioner, agent of change and a researcher (CAR). The division of labour of the learners include that they are ‘scientists’ conducting fieldwork and the scientific method. The object of this activity system is to enhance affective outcomes from the CAR, namely inculcate enjoyment, excitement, appreciation and engagement. Engeström (2009) highlights that the object should be permeated into the activity system, furthermore there is complexity of the object called ‘contradiction of control’ (McNeil, 2013). In the ideal context there should be a shared view to achieve the object (Mentz & De Beer, 2017). Whereas there often are ‘conflicts’ in terms of

contradicting (non-aligned) objects in the two activity systems, it is surprising to see that, in this case, there was good alignment between the objects in the two activity systems.

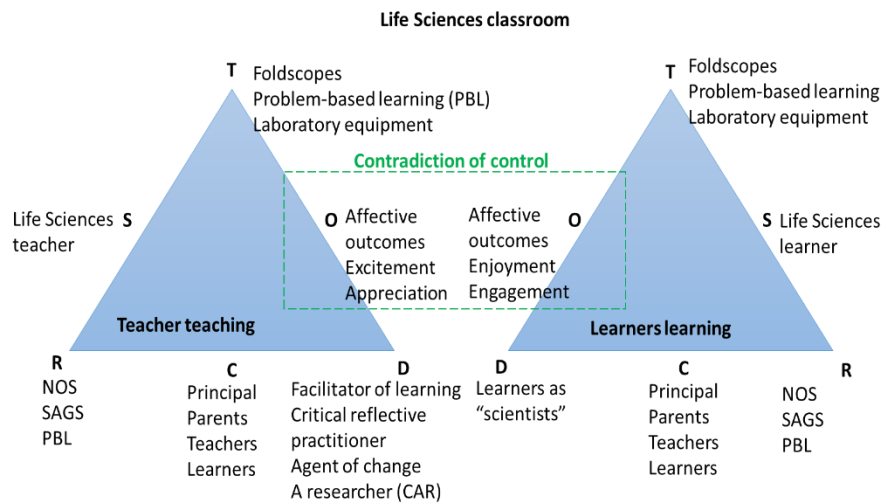


Figure 3: Using the Third-Generation Cultural Historical Activity Theory (CHAT) the unconventional way: Comparing the Life Sciences teacher and the learner adapted from Engeström (1987) and de Beer & Mentz (2017).

CONCLUSION

Not only did teachers indicate that their engagement in CAR assisted them to become more critical reflective practitioners, but the learners also achieved valuable affective outcomes through their participation in the Foldscope learning activity. Teachers that engaged in the CAR found it very stimulating and exciting to create successful activities that contributed to learners' enjoyment of science. Teachers also improved their research skills, which hopefully enhance teaching and learning in the Life Sciences classroom.

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DECODING OF SCIENCE TERMINOLOGY IN SOUTH AFRICAN PRIMARY SCHOOLS

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ABSTRACT: In this paper, we explore the teaching strategies used by three South African primary school educators to decode science terminology in Grade 4 classrooms. In South Africa, the study of science is formally introduced to learners in Grade 4, when they transition from being taught in their native languages in Grades 1 to 3, to being taught in English. This presents the challenge of learning a new subject in an unfamiliar language. The way educators decode science terminology during science lessons could affect learners' comprehension of science vocabulary. Research shows that the majority of South African primary school learners find science terminology difficult to comprehend due to linguistic challenges, which could account for their poor performance in science assessments. Semi-structured interviews were used to collect data in a qualitative case study, to find out how three science educators teach and decode science terminology in Grade 4. The study findings suggest that the participating educators use ad hoc teacher-centered teaching strategies to decode science concepts. These findings have implications for the preparation of primary school science educators in teacher training institutions.

Keywords: Terminology; teaching strategies; decoding; primary school; educators; science

INTRODUCTION

The scientific literacy of most South African learners has been of concern to many scholars and policy makers (Lelliott, 2014; Pouris, 1991). According to Dragos and Mih (2015:168), scientific literacy is "the ability of an individual to understand scientific laws, theories, phenomena and things". For learners to be successful in science, they need to develop the capacity to read and understand scientific texts; construct texts appropriate to the learning area; think about, discuss, interact with; and use these texts in subject-specific contexts (Gay, 2010). Beyond the comprehension of the overall meanings of science as a subject, learners are also expected to actively engage in observations and interactions with learning materials, educators and their peers, as they explore new science terminology and expand their understanding of science (DoBE, 2011). These activities require learners to be proficient in both the language of science and the language of instruction, which in the South African context is English. In South Africa, learners are formally introduced to the study of science in Grade 4, where they learn the language of science, its principles and rules in English. At this time, primary school learners transition from being taught in their native languages in Grades 1 to 3, to being taught in English in Grade 4 (Pretorius, 2014; DoBE, 2011). Therefore, they get to Grade 4 with limited proficiency in English. At the same time, learners need to develop more book-oriented academic literacy skills to cope with the increasing literacy challenges of the Intermediate Phase (Pretorius, 2014). Learners are therefore faced with multiple learning challenges in Grade 4. This is particularly challenging for most South African learners who use English as second or even third language (Snow, 2010). According to Pretorius (2014), learners in Grade 4 across South African schools struggle with learning science, as it their first time to study the subject, which is taught in an unfamiliar language.

Learners need to be able to read the academic language, which guides the activities, communication, and inquiry that constitute science, in order to engage with the subject (Hand, Yore

& Bisanz, 2003). It therefore becomes critical for educators to be able to decode scientific statements and terminology for learners' comprehension of science. Decoding science terminology refers to the understanding and interpretation of terminology found in the field of science (Snow, 2010). Gay (2010) asserted that teaching and learning are culturally determined and are not the same for all. This is especially true for most South African schools, where there is diversity of cultures, social backgrounds and linguistic backgrounds. In this regard, Cochran-Smith (2001) argued that educators, within the South African education system, should use varied teaching strategies, to help the learners understand subjects better. Primary school science educators are therefore called upon to teach science in ways that make it accessible and engaging for all learners (National Research Council, 2012). Literature suggests that the use of learner-centered and community-centered teaching strategies, such as inquiry-based learning (Padilla, 2010) and cooperative learning (Alexander & Van Wyk, 2014), in science classrooms could enhance learner performance in science, by allowing them to own their learning (Maluleke, 2015).

Despite the availability of engaging instructional strategies, Carrier (2013) observed that most science educators teach science terms using traditional teaching methods. These methods often begin with educators presenting learners with science vocabulary and asking them to carry out activities such as writing down the words; finding the definitions from a dictionary or the glossary of the textbook; matching words to definitions, or use of the terms in a sentence. The teaching strategies used by South African Grade 4 educators to decode scientific concepts to help learners make sense of science texts, within a limited time allocation of 3.5 hours per week (DoBE, 2011), are not well documented. The study reported in this paper explored the teaching strategies used by three South African primary school educators to decode science terminology in Grade 4 classrooms. The following research questions were investigated:

1. Which science terminology are perceived to be difficult for South African Grade 4 learners to understand?
2. Which teaching strategies do the educators in the study sample use in Grade 4 science classrooms?
3. How do the educators in the study sample decode science terminology in Grade 4?

CONCEPTUAL FRAMEWORK

Bransford, Brown and Cocking's (1999) model of 'How People Learn-HPL', guided the evaluation of the teaching and word decoding strategies used by the educators who participated in this study. The model consists of a combination of four instructional designs, namely: Learner-centered; Knowledge-centered; Assessment-centered and Community-centered instructions, as shown in Figure 1.

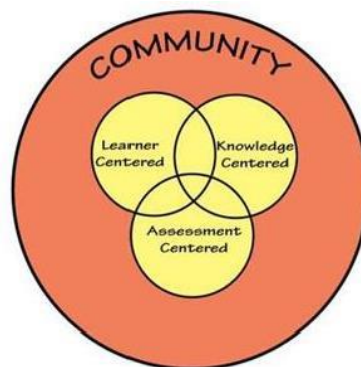


Figure1. How People learn - HPL Model
(Adopted from Bransford, Brown & Cocking, 1999)

According to the HPL model, learner-centered instruction involves the development of knowledge, skills, attitudes and needs of learners, by actively engaging them in lessons. Knowledge-centered instruction focuses on helping learners develop a deep understanding of the content and processes of a discipline. Assessment-centered instruction emphasizes formative and summative evaluation of learners and the provision of frequent feedback and revision. Community-centered instruction refers to instruction based on a community of learners within a learning situation, and connected to the community at large. Bransford, Brown and Cocking (1999) posited that a combination of these four instructional designs maximizes learning. Other researchers have suggested similar instructional approaches for effective science learning (Alexander & Van Wyk, 2014; Fitzgerald & Smith, 2016; Padilla, 2010).

METHODOLOGY

A qualitative case study research design was used to collect data from three, purposively selected Grade 4 educators. The educators came from schools in the Gauteng province of South Africa. All the participants had taught Grade 4 science for at least four years, and were able to communicate in English. Table 1. shows the profiles of the educators who participated in the study.

Table 1: Profile of study participants

Participant	Gender	School code	Qualification	Teaching experience (years)	Area of specialization
Educator 1	Male	X	Higher diploma in primary school education; diploma in education management; and HR certificate	19	Science
Educator 2	Female	Y	B.Ed. and B.Ed. honors' in Mathematics and Science	25	Science and Mathematics
Educator 3	Female	Z	B.Ed. in Science education	4	Science

DATA COLLECTION AND ANALYSIS

After obtaining ethical clearance from all stakeholders and explaining the ethical rights to the participants, semi-structured interviews were used to collect qualitative data from individual participants. The interview items focused on difficult science terminology taught in Grade 4, and the teaching strategies commonly used to teach science and to decode science terminology. The interviews were held in the staffroom or in the participants' classrooms, outside teaching hours. Recorded interview responses were transcribed and coded using specific notations as shown on Table 2. For instance, the code 'A1iv', represents a statement related to theme A, given by educator 1, as response statement number 'iv'.

Table 2: Notations used to transcribe interview responses

Themes	Participants
A-Represents the theme: Difficult Grade 4 Science terminology	1-Represents the first educator
B- Represents the theme: Instructional strategies used to teach Science	2-Represents the second educator
C- Represents the theme: Decoding of Science terminology	3-Represents the third educator
Roman numerals represent the number of the statement provided by a participant in each theme.	

The transcribed and coded statements were shared with the participants to ensure their accuracy and transparency of the study. Thereafter, the coded responses were analyzed using content data analysis.

FINDINGS

The participating educators were asked to identify the science terminology from Grade 4 CAPS document, which they perceive to be difficult for learners to understand. Table 3. shows the terms frequently identified by the three educators as difficult for Grade 4 learners. The researchers corroborated these terms from the CAPS Grade 4 science content (DoBE, 2011).

Table 3: Difficult Science terminology in Grade 4

Science strand	Difficult Science terminology
Life and living	Living, non-living, structure, plants, habitats, skeleton, yeast, reproduction, fertilized, sensing, breathing and excreting.
Matter and materials	Materials, ceramic, solids, cycle, vapor, condensing and solidifying.
Energy and change	Photosynthesis, process, wavelength, energy, transfer, sound, impaired, vibration and plucking.
Planet earth and beyond	Planet, rocket, solar, system, sediment, rock, galaxy, constellation and comet.

Participating educators were also required to explain the teaching strategies, which they use during Grade 4 science lessons. The first and third participants indicated that they initially use question and answer to determine learners' prior knowledge and then build around that information, using other strategies such as discussions or demonstrations, as indicated in the following quotations.

B1i Mmmh, question and answer, I use the the.....mostly question and answer then sometimes I link with the previews question, like for instance, when I start the lesson, I will ask a questions.

B3ii Mainly question and answer, then discussion and demonstration to be involved in understanding certain things.

The second, participant said that she explains the concepts first, and then use different teaching strategies to develop the lesson. She however did not specify the teaching strategies used, apart from stating that she gives classwork at the end of a lesson.

B2i The teaching strategies uuuh, u teach them, ya u teach them, you explain first, about the concept what does it mean, you go about the concept and clearly explain and then you get the gist, so that they can understand and towards the end you give them classwork so that you can see they understand.

Finally, the educators were asked to explain how they decode difficult science terms to make sure that learners understand them. Educator 1 did not seem to understand the term 'decode'. However, after explaining the term, he explained that he uses the recommended textbooks (which he did not name) to provide definitions of terms, as stated below.

C1ii The big words, okay okay, ya! The textbooks have key words on the side so it is easy for them to understand because it is like a dictionary, it says a word and then it explains it.

In response to the same question, educator 2 laughed and paused for a long time, and later responded that she brings objects to class and uses pictures to explain science terminology. Her response is stated below.

C2i Ummh... sometimes u use, let me say coming to uhm (laughs) just wait a little bit, let me say you bring objects in the class; bring objects in the classroom. Sometimes you comprise [*improvise*] because our schools do not have the instruments. Sometimes you just bring a picture so that they can see the kind of thing you are talking about or even in the book, you will find the drawings are there but you do not have the real objects to show them.

Educator 3 said she uses practical examples or whole reading and a dictionary. She emphasized that it is important for learners to read, as quoted below.

C3ii To decode uuumh, science terminologies? As I said, apart from doing practical examples, reading, whole class reading is important because some of the learners in Grade 4 struggle with reading, the syllables of the word and all those things, is important to read, mainly whole class reading and they have concepts dictionary, they do those concepts as a form of classroom activity.

When prompted to provide details of how they use the cited teaching strategies, the educators could not elucidate further, they instead reiterated the use of verbal explanations, individual and class reading, writing words on the board, demonstrations, practical examples, and the use of pictures and dictionaries or textbooks. The educators failed to provide credible answers when asked to describe the type of dictionaries used, and to explain why they use dictionaries to decode science terminology.

The CAPS (DOE, 2011) proposes some teaching resources and a variety of instructional methods, such as inquiry and cooperative learning, for teaching new information. When asked about the usefulness of these teaching strategies in decoding science terms, the three educators were evasive. Educator 1 did not respond to the question, and the other educators simply mentioned that the CAPS document is very helpful to educators, without providing detail, as indicated in the following extracts:

C1v Ijoooh! That is... I do not know (laughs). Ai no!!

C2iii Eeeh (thinking) it makes it easier for educators to teach science, especially in the primary level, especially new educators.

C3V They are helpful in a way especially when you look at the skill in natural science,... so it is very much helpful depending on the concepts you are dealing with.

Two of the participants complained about lack of teaching aids in township public schools, as exemplified by the quotation below.

C2iv I wish we could have so many, eeeeh learning aids, and uuhhhm, the modern things, I think it will be better for the educators, like myself because I cannot draw, I can draw but the picture I'm drawing is not good enough for them to capture very clearly. If the school can buy the material or learning aids, it will make the work easier.

When the two educators were pressed to explain how they ensure that learners understand science terms during science lessons, in the absence of teaching aids, they explained that they help learners in every way possible, including explaining science terms in vernacular. The third educator was quick to mention that code switching to vernacular could help learners in the short term, but learners are likely to fail science examinations, which are written in English, because learners struggle to express themselves in English during oral or written assessments.

DISCUSSION OF RESULTS

Several researchers have acknowledged some of the terms identified by the educators as difficult for Grade 4 learners (Cervetti, Hiebert, Pearson & McClung, 2015). However, different educators are likely to perceive the difficulty of science terms differently, depending on various factors such as, duration of exposure to the terms, availability of appropriate resources and educators' comprehension of the terms. Some of the participants in this study appeared to be unfamiliar with some of the identified terms, as they could not explain them clearly, when asked to do so. It is therefore possible for such terms to be ignored by educators during science lessons.

The findings revealed that participating educators mostly used teacher-centered teaching approaches, such as explanations, question and answer, writing terms on the board, dictionaries, demonstrations and practical examples, to teach science. This finding is not surprising, as various researchers have found similar results (Carrier, 2013; Hobden, 2005). The interview responses showed that educators did not have well planned systematic ways of decoding science terms. They rather used the stated instructional approaches in an ad hoc manner. This is disheartening given the enormous challenge of learning science in an unfamiliar language, faced by most South African Grade 4 learners (Snow, 2010). Failure to prioritize and clearly decode science terminology could limit learners' scientific vocabulary, which could partly account for the poor performance of the majority of South African primary school learners in national and international science assessments (Pretorius, 2014; Reddy, 2006). Literature suggests that new words should be introduced to learners explicitly and should be bound to hands-on scientific investigations (Cervetti, et al., 2015). This suggestion aligns well with the learner-centered component of the HPL model of instruction (Bransford, et al., 1999). Cervetti, et al also proposed the use of new terms by learners when summarizing and reflecting on their learning of science units, which entails learner-centered learning.

It is clear from the responses obtained from interviews that, while the educators revealed some evidence of knowledge-centered and assessment-centered teaching, their teaching approaches largely fall short of learner-centered and community-centered instructions. These latter components of the HPL instructional model are associated with science teaching approaches such as inquiry-based and cooperative learning, which have recently re-emerged as crucial science instructional strategies. These teaching approaches are not only necessary for effective science learning (Alexander & Van Wyk, 2014; Fitzgerald & Smith, 2016; Padilla, 2010), but also for the development of the higher order thinking skills required for effective citizenry in the 21st Century (Trilling & Fadel, 2009). The lack of these instructional approaches and the prevalence of knowledge-centered and assessment-centered teaching in South African science classrooms, especially at early primary school, could be the root cause of the high incidence of memorization of science content, without understanding. Lack of understanding of science content could partly account for the abysmal performance of most South African learners in national and international science assessments (Lelliott, 2014; Pretorius, 2014). Assertions of lack of teaching aids are genuine, and can be a significant impediment to effective science teaching, as pointed out by some of the participants. However, most primary school science activities do not require complex and expensive teaching materials. Educators could easily improvise by using cheap day-to-day household products.

CONCLUSION AND RECOMMENDATIONS

In conclusion, the study findings seem to suggest that the participating educators did not have well planned strategies for teaching and decoding science terminology. They commonly used teacher-centered teaching methods. We recommend a shift from teacher-centered to more learner-centered and community-centered instructional designs, such as inquiry-based and cooperative learning, which could enable learners to own their learning (Maluleke, 2015). These instructional strategies are also likely to develop the necessary skills for learners to participate in the fourth industrial revolution of the 21st Century, effectively. Educators' complaints regarding lack of teaching aids could signify incompetence in learner-centered teaching strategies and in improvisation. We therefore recommend the accentuation of learner-centered instructional approaches in Intermediate Phase teacher training programs, to develop the necessary skills in educators. The finding of the study should be viewed in the context of a limited sample of educators. A study with more participants is recommended to shed more light on these findings.

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ENHANCING PRE-SERVICE TEACHERS' SCHOOL EXPERIENCES THROUGH MENTOR OBSERVATION AND REFLECTION

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ABSTRACT: This is a qualitative study of Bachelor of Education Life Sciences students in their third year of teacher education. These pre-service teachers taught in different schools for one week, herein referred to as Work Integrated Learning (WIL). WIL experiences expose pre-service teachers to the real classroom situation where they can apply theory into practice, which differs from the 'staged classrooms' referred to as micro teaching done at university when they teach their peers. The study sought to answer two research questions: (1) what pedagogical practices do pre-service teachers develop from mentor observations? and (2) how do they reflect on their mentor practices? Each pre-service teacher taught a lesson to either grade 10 or 11 life sciences learners; got feedback from mentors, observed the mentor teaching a lesson and then answered questions given by the researcher, which facilitated development of critical reflective skills. Through content analysis of the reflections, the findings showed pre-service teachers' appreciation of the importance of teachers possessing adequate subject matter knowledge and pedagogical skills. They had opportunities to articulate what they had learned from observing their mentor practices. Reported mentor weaknesses and strengths can be used to design professional development programmes for mentors on effective mentoring practices.

Keywords: Pre-service teachers; mentor teachers; reflection

INTRODUCTION

Mentor teachers have shared responsibilities with university teacher educators to develop pre-service teachers in terms of pedagogy, curriculum interpretation and implementation. Mentors should model appropriate classroom practices; which pre-service teachers learn from through imitation. In essence, feedback from the mentors may facilitate continuous development and improvement of pre-service teacher practices through reflection (Sempowicz & Hudson, 2011). Sempowicz and Hudson noted that pre-service teachers can only improve their teaching practices when they observe, practise, reflect on and improve decision making on planned lessons, and interactions with learners and other practising teachers. In this way, full transition from university theory to actual effective teaching can be achieved.

LITERATURE REVIEW

Researchers have put forward different models of teacher reflective practices for example the three levels postulated by Frick, Carl and Beets (2010), where teachers develop their identities as professionals, develop a sense of purpose (mission) and develop metacognition. Lee (2005) brought forward three levels as well, practical/technical, contextual/deliberative, and critical/dialectical. In both models, issues of context and intention are inherent. As such, it implies that to ensure effective reflection that translates into improvement of practice, pre-service teachers should be given a goal to achieve when they observe their mentor teachers' practices. This study is part of a larger study focusing on the role of the mentors in effecting pre-service teachers' professional development. The current study seeks to determine how pre-service teachers learn from observing their mentor practices and reflect on these practices for their own development. Hudson (2010) describes teaching as an interpersonal, emotional and social profession, which therefore emphasises the

importance of the interaction between mentor and mentee and at the same time the intentional effort by the mentee to self-development. It is important to identify and recognise mentoring patterns, strengths, weaknesses and challenges, as this will help in planning mentor professional development programmes.

The role of reflection on teaching practices

Reflection and collaboration have been found to be dependent on each other in promoting teacher professional development (Cuesta, Azcárate & Cardeñoso, 2016). In this case reflection refers to practical deliberation and critical reflection (Cuesta et al, 2016), which takes place in a practical context (science classroom), with pre-service teachers exercising their judgement about the teaching practices of their mentors. Goethal, Howard and Sanders (2004) described reflection as a process of careful and deep thought about all planned and unplanned activities and behaviours done in a particular setting. Through critical reflection of their mentor actions, pre-service science teachers could gain awareness of their underlying beliefs, shortcomings, strengths and possibilities for development. Through this kind of reflection, it is hoped that pre-service teachers will continue learning about teaching and about themselves as teachers. Because pre-service teachers possess a fledgling version of professional knowledge, they are more receptive to innovative ways of teaching that they observe from their mentors considering that chances of resistance are minimal since they do not have deeply rooted traditional experiences (Cuesta et al., 2016). It is important for teacher educators to inculcate a culture of reflection in pre-service teachers for them to critically analyse obstacles on effective teaching and learning (Davis, 2006; Lai & Calandra, 2010).

The study used Pedagogical Content Knowledge (PCK) as the conceptual framework. Capturing teachers' PCK for both beginning and experienced teachers has been done in different ways for example use of Content Representations (CoRes) and Pedagogical and Professional experience Repertoires (PaP-eRs) (Loughran, Mulhall & Berry, 2004; Nilsson & Loughran 2012). Teachers' interview scripts, lesson plans, artefacts and video recordings of observed lessons (Friedrichsen, Abell, Pareja, Brown, Lankford & Volkmann, 2009; Henze, Van Driel, & Verloop, 2008; De Jong, Van Driel, & Verloop, 2005; Wongsopawiro, 2012), can also be used to capture and assess teachers' PCK.

Normally mentees do not get an opportunity to be in the shoes of the mentor, as such they lose opportunities to reflect on someone else's practices. In addition, rarely do pre-service teachers get the opportunity to articulate what they have learned from observing their mentors. In most instances, they are expected to translate those observations into action. The focus of the study was two-fold, (1) investigating how pre-service teachers learn from their mentor practices other than through feedback and, (2) determining the pre-service teachers' abilities to identify good and bad practices from their mentor practices. The study sought to answer the following research questions:

1. What pedagogical practices do pre-service teachers develop from mentor observation?
2. How do they reflect on their mentor practices?

Context of the study

At the beginning of first semester, 130 pre-service Life Sciences teachers had a week long WIL experience, where they observed many lessons of their mentors teaching Life Sciences learners of grades 10-12. The focus of the observations was on teaching and assessment strategies employed by their mentors. These pre-service teachers had a critical discussion in the report back done during a lecture after their WIL. The current paper does not report on this experience but rather on their experience during their second WIL in September.

METHODOLOGY

The research took the form of a qualitative case study (Creswell, 2014) with the overall purpose of determining and understanding pre-service teachers' professional development processes resulting

from observing and reflecting on their mentor practices. After an intense semester course on Life Sciences Methodology and Practicum, a course meant to prepare students for engaging in school experience, pre-service teachers had another week long WIL experience in various schools surrounding Johannesburg. They each taught a minimum of one lesson, which they were assessed by the mentor teachers and got feedback. They then observed their mentor teachers teaching. To ensure reflection that enhances practice (Frick et al., 2010; Lee, 2005), pre-service teachers were provided with questions to consider whilst observing their mentor teachers. The questions required them to report on the classroom context, strengths, weakness and challenges of the lesson, and opportunities for learning presented in the lesson. The current paper reports on only 30 pre-service teachers' reflections of their mentors' teaching practices, which the researcher postulates as focal opportunities for pre-service teachers to enhance their pedagogical skills.

Normally mentor teachers facilitate pre-service teachers' critical reflective abilities through dialogue when giving feedback on the mentee's observed teaching practices (Brandt, 2008). The current study focusses on developing the same reflective abilities when pre-service teachers critically observe their mentor teaching practices with the aim of improving own practice. The study explored reflective practices in relation to the pre-service teachers' answers to the questions on their mentors' practices. In this way, they were forced to reflect on their own practices. The sequence of data collection is presented in Figure 1.

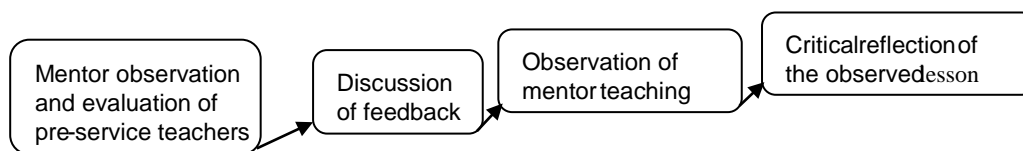


Figure 1: Summary of data collection events

Data collected was subjected to content analysis. Content analysis is a flexible method for analysing text data (Cavanagh, 1997) and in this case the text came from pre-service teachers' reflections. Qualitative content analysis involves interpretation of the content of text data by systematically coding and identifying themes or patterns (Hsieh & Shannon, 2005). The codes were categorised deductively using the key aspects in the questions given by the researcher. To promote more dependability on the data, coding was done as soon as data were collected and then recoded after some time and then results compared (Krefting, 1991). Four major categories emerged, which are discussed under research findings and discussion.

RESEARCH FINDINGS AND DISCUSSION

The findings of the study (four categories) are presented under the following subheadings: (1) classroom context, (2) teacher strengths, (3) teacher weaknesses and challenges, and (4) opportunities for learning presented from the lessons. By identifying opportunities presented in the lesson that they could learn from, the assumption is that pre-service teachers developed professionally and emulated those pedagogical practices. By identifying the weaknesses displayed in mentor lessons, the pre-service teachers will work towards improving such situations when they are teaching.

Classroom context

Most of the pre-service teachers worked in township schools which were equipped with smartboards and white boards provided by the department of education. From the pre-service teachers' reflections, there were different descriptions of the suitability of the classroom context. Descriptions included issues of classroom sitting arrangements, the environment surrounding the classroom, opportunities given to learners to exercise autonomy in their learning, teacher-learner

and learner-learner interactions. For some, because the classrooms were overcrowded with an average of 48 learners in each class, there was hardly any space for the teachers to move around to supervise learners or give individual attention to learners. In such cases, the participants described the context as 'an uninviting classroom environment where learners were seated in a row all facing the front of the classroom, leaving no room for learner-learner interactions'. Hence learners could have pretended to be attentive as there were no signs of engagement. As such, teaching was teacher-centred. Such descriptions of classroom contexts are not new because previous research (see Marais, 2016; Matshipi, Mulaudzi & Mashau, 2017) has reported difficulties experienced by student teachers when teaching large classes. This is unfortunate because in theory the maximum recommended learner-teacher ratio for South African secondary schools is 35:1 (Motshekga, 2012), but in reality this is not the case.

Other pre-service teachers complained that noise from outside disturbed the smooth flow of the lesson, as learners got distracted. Noise from outside could not be controlled because of broken windows and doors. Other pre-service teachers described the classroom context as a positive and conducive environment for teaching and learning. Such comments included, 'healthy relationship between the teacher and learners, which provides an opportunity for learners to have a voice in their learning and learners given an opportunity to work in groups and individually'.

Mentor teachers' strengths

The pre-service teachers reflected mostly on the mentor teachers' subject matter knowledge and pedagogical skills. They indicated that the mentors showed mastery of the content that they were teaching, which enabled them to explain the concepts in a comprehensible manner for the learners. It should however be noted that there were some negative comments in this respect where due to lack of thorough preparations, certain mentors were found wanting. This is reported under weaknesses. On the pedagogical aspect comments such as, "...due to many questions asked, learners participated, teacher used group discussions and collaborative learning and used illustrations and flow diagrams", were common in some pre-service teacher reflections.

An important aspect noted by the pre-service teachers was their realisation that the mentors' abilities to speak audibly, making eye contact with the learners and showing enthusiasm of what they were teaching, contributed to learner engagement with the content. Some of the comments included, 'Teacher's content knowledge of the circulatory system was evident and he was enthusiastic about what he was teaching; the teacher managed both the time and learner behaviour quite well. It is important to note how some mentors could model teaching large class sizes as evidenced by the statement, 'Due to lack of adequate resources, my mentor demonstrated a practical activity and allowed learners to take turns to observe and make readings for example'. The pre-service teachers realised that good classroom management skills allow efficient utilisation of time, coordination of resources and activities. Other strengths mentioned included teachers constantly involving learners in question and answer sessions, which assessed learners' understanding of the concepts taught and teachers' use of real life examples and situations familiar to learners. This helped to engage learners in the learning process as learners realised the relevance of the content they were learning in their lives.

Mentor teachers' weaknesses and challenges

As indicated earlier, there were also some mentors that had challenges in explaining biological concepts. For example some of the comments to this respect were; 'My mentor failed to properly teach the relationship between the blood circulatory and lymphatic systems to grade 10 learners. 'The learners showed confusion on their faces and started asking questions, which the mentor could not easily answer'. 'I realised the importance of thorough preparation before teaching because it was embarrassing listening to my mentor struggling to clearly explain when teaching the structure of

the kidney nephron and its role in reabsorption and pH control'. According to these pre-service teachers, the mentors generally bailed themselves by rechannelling questions to the class and involving learners in discussions but never summarised the important concepts afterwards. It was also pointed out that in order to show that these mentors were not adequately prepared, they failed to anticipate learner difficulties and questions. Therefore such mentors showed poorly developed PCK though experienced because Shulman (1986) categorised two key components within PCK, which are knowledge of representations of subject matter and understanding of specific learning difficulties and student (alternative) conceptions.

Some of the weaknesses mentioned included mentors speaking in monotonous voices, which did not attract learner attention, failure to use illustrations and diagrams in explaining the concepts and failure to identify appropriate resources when teaching specific concepts. The comment that some of the mentors read texts from a textbook and then summarised the concepts on the board was viewed as a strength by some pre-service teachers and as a weakness by others. It was interesting to note that the pre-service teachers identified weaknesses by the mentors such as failure to conclude the lesson due to poor time management and not much effort placed in probing for learner prior knowledge and identifying and addressing misconceptions, which normally is their own weaknesses. Challenges faced by mentors included large classes resulting in learners failing to get individual attention and lack of resources such as laboratory equipment and lack of enough textbooks for all learners to refer to.

Opportunities for learning presented from the lesson

Teacher educators and mentors have always given pre-service teachers opportunities to observe others teaching but they rarely give them opportunities to articulate what they have learned from those observations. In the current study pre-service teachers reported that from the observations, they realised that instilling and maintaining discipline allows meaningful teaching and learning to take place. They also noted that variation of teaching and learning strategies invokes learner interest in the content being taught. Pre-service teachers realised that proper pacing of activities in a lesson is important as the teacher gets time to summarise the concepts taught and give learners homework or assignment. According to their comments, such pacing was achieved by the teachers adhering to the time allocated for each activity, which stems from proper planning of the lesson. Pre-service teachers learned that it is important to select an appropriate teaching strategy and resources for the lesson and use them productively rather than using a barrage of strategies but fail to adequately engage learners. 'A motivated teacher creates a motivated group of learners', were the actual words of one of the pre-service teachers. They also realised the importance of being a caring teacher who communicates effectively, as this facilitates exchange of ideas and helps in identifying mutual concerns that affect classroom teaching and learning environment. Such an environment promotes development of critical thinking in learners. They also mentioned that when concluding a lesson, it is important for learners to share what they have learned instead of the teacher summarising important concepts covered.

Interestingly the pre-service teachers came up with a set of instructions for good teaching practices such as: teachers need to refer to various sources of information when planning a lesson as this enriches his or her repertoire of examples, activities and representations of the concepts in different ways. To quote some of the comments, '....do not just expect learners to understand or remember content, challenge them to learn how to apply the knowledge they have acquired; learners need to be challenged for them to think and apply the content in unfamiliar situations'. From the research findings, it shows that by giving pre-service teachers questions about their mentor practices, they managed to identify, conceptualise and learn better teaching practices. Similarly, in a survey among student nurses Duffy (2009) found that guided-based reflective practice on pedagogical content knowledge was successful in assisting student nurses to reflect deeply and critically.

CONCLUSION AND IMPLICATIONS

It can be concluded that when given questions to guide their observation, pre-service teachers could identify mentor strengths, weaknesses, challenges and classroom context, which they could learn from. The findings of this study provide implications for university teacher educators and department of basic education in-service providers with important information on the strengths and shortcomings of the mentors. Such information can be used to design professional development programmes for mentors on effective mentoring practices, an area which is neglected in teacher education.

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PRE-SERVICE TEACHERS' UNDERSTANDINGS OF CHEMISTRY CONCEPTS USING VIRTUAL AND HANDS-ON LABORATORIES

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ABSTRACT: The use of experimentation in science teaching is one of the most advocated strategies for teaching abstract concepts in school science. Lab-based experiments have been used and proven to enhance learners' understandings and boost learner performances in content tests. However, the physical resources for enacting hands-on experiments are most often limited in poorly resourced schools. In the wake of the fourth industrial revolution, the use of virtual online laboratories, have provided alternative solutions for chemistry learning. In this baseline experimental study, we provided a group of third year pre-service sciences teachers ($n=50$) with four chemistry concepts to learn using a hands-on (control) and a virtual laboratory (Experimental). The same Pre and post chemistry content test was administered to the both groups of students, before and after learning interventions. Test scores were analysed and results of paired-sample t-test showed a statistically significant difference between pre and posttest results for all groups of students. Using independent sample t-test, we further compared posttest scores for the control and experimental groups which revealed the mean posttest score of the experimental group ($M = 79.36$, $SD = 8.306$) being significantly higher than that of the control group ($M = 68.72$, $SD = 9.076$) and $t(48) = 4.32$, $p < .01$. Based on these findings, laboratory interventions were found to have an impact on student's understandings of the assessed concepts, with virtual laboratory interventions enhancing higher achievement than traditional laboratories. Implications of these findings and recommendations for practice and research are also discussed.

Keywords: Hands-on laboratories; virtual laboratories; conceptual understandings; content test

INTRODUCTION

Laboratory-based science teaching has been proven to play a significant role in learners' understandings of abstract scientific concepts (Estapa, & Nadolny, 2015). As postulated by early constructivist theorists, experiential and experimental learning have the ability to enhance cognition significantly (Bruner, 1990). This improvement in cognition is associated with the relationship between visualisation and the formation of mental schemas and representations (Mayer, 2011). Chemistry is a core science subject, which cuts across all other sciences including physics, biology, engineering and geological sciences, in terms of its content. For the South African education system, the need to learn science by inquiry has also been widely advocated within curriculum documents and research output (Department of Basic Education [DBE]: Physical sciences, 2011; Dudu, 2014; Gaigher, Lederman & Lederman, 2014; Ramnarain & Schuster, 2014; Hsu, Lin, & Yang, 2017). However, with the scarcity of resources in the current economic times, the financial implications of providing each school with its own traditional chemistry laboratory is extensive. It is therefore imperative that science teachers explore alternative pedagogic strategies, which can meet learners' visualisation needs when dealing with abstract chemistry concepts, like the atomic structure, chemical reactions, spectrophotometry and many others. In the case of schools, which already have the provision of traditional laboratories, the issue of large class sizes, time constraint and scarcity of ongoing support funds are among some of the other constraints (Hsu et al, 2017; Yen, Tsai, & Wu, 2013), which affect laboratory learning.

With the advancements registered in technology within the last three decades, learning with the use of technology has been widely advocated, as a means to overcome the barriers of time and

geographic location for learners. Virtual laboratories developed with software have been created in several online spaces to enhance science learning. These virtual laboratories spaces can be used by educators, not as replacements for physical hands on chemistry laboratories, but as learning tools to complement physical laboratories (Hsu *et al*, 2017; Makranskya, Terkildsen, & Mayer, 2017; Wu, Lee, Chang, & Liang, 2013).

VIRTUAL AND HANDS-ON LABORATORIES IN SCIENCE TEACHING

In the advent of the fourth industrial revolution, the incorporation of technology in science teaching provides a platform to bridge some of the gaps in traditional science teaching and learning. Virtual laboratories are technological tools, which provide users with a simulated imitation of a real laboratory experiences (Chiu, De Jaegher, & Chao, 2015)). Virtual reality software has been extensively used by developers, educators and researchers to provide learners with an alternative platform in which science concepts can be investigated (Wu *et al*, 2013). Within these virtual laboratories, learners can learn science by experimentation and other non-experimental forms of inquiry. This current study investigated Pre-Service teachers' use of hands on and virtual laboratories in learning in four chemistry concepts including, acid-base solutions, chemical reactivity, beer's law (spectrophotometry), atomic structure and isotopes. The physical hand-on laboratory at one of the city's elite secondary schools was used for learning interventions with the control group while, the free online-simulated virtual laboratories (PhET) provided by the University of Colorado, of the United States of America were used to facilitate the virtual laboratory experiences for the experimental group. The question of whether, virtual laboratories can replace hands-on laboratories in science teaching is a difficult one to answer for researchers, science teachers and learners. This has left many educators and researchers inquisitive about the affordances of incorporating virtual learning in science education and the effects of using virtual labs on several factors including, learners' concept understandings, attitude towards science, interest in STEM careers and the fundamental understandings about the nature of scientific inquiry. Some of the advantages and disadvantages associated with using virtual and traditional laboratories are outlined below.

Virtual laboratories

Advantages; Virtual laboratories are cheaper to create and maintain than physical laboratory.

They can be accessed from anywhere, at any time. A teacher is not needed to facilitate and manage activities within a virtual space. Experiments can be repeated severally without wasting of chemicals or other resources. Less time is required to complete the given tasks because there are no physical preparations required prior to starting an investigation. Learners can engage in open and discovery learning without any fear of failure. The interactive virtual interphase is captivating and keeps learners engaged for longer (Wu *et al*, 2013).

Disadvantages; Some disadvantages of using virtual laboratories include mainly the hazards of prolonged exposure to computer screens. In addition, disengagement from reality due to immersion into a virtual space can be very problematic for learners and the creation of tangible and physical products cannot be archived in a virtual learning laboratory space.

Traditional laboratories

Advantages; the advantages of using traditional hands-on laboratories include the fact that, hands-on authentic experimentation can be achieved, products are tangible, science process skills and equipment handling can be learned in a real environment.

Disadvantages; some of the disadvantages of using traditional laboratories for science learning include the expensive cost of creating and maintaining them. These laboratories also have a higher risk factor for learners when they conduct dangerous chemistry experiments. The traditional laboratory cannot be accessed by learners at all times. Teachers and other human resources are needed to manage and facilitate the use of these traditional laboratories. In addition, a large

number of learners cannot be accommodated in most traditional school laboratories at the same time and more time is needed to prepare and carry out all investigations.

THEORETICAL FRAMEWORK

The study assumed a multi-theoretical framework, which combined the principles of constructivism (learning by active participation and experimentation), the proposed integration of technology into Shulman's Pedagogical Content Knowledge (PCK) (Shulman, 1987) and the cognitive theory of multi-media learning (Mayer, 2011). The Technological Pedagogical and Content Knowledge (TPACK) framework advocates that, learning can be facilitated when technology is used to complement teaching using the right pedagogical approaches (Koehler and Mishra, 2008; Swallow & Olofson, 2017). On the other hand, the theory of multi-media learning posits the use of multiple media (auditory and visual) media, in teaching and learning as an excellent tool for facilitating the visualising of abstract concepts and the creation of mental representations (Mayer, 2011). The overarching constructivist theories which promote learning by experimenting and interacting with the object of interest as a means through which conceptual understandings can be attained also served as the main underpinning for the study. The preservice teachers who were the learners in this case, engaged in all the laboratory activities with little guidance. With these well-exploited theories and the view that, active participation in constructing scientific knowledge is paramount for understanding abstract science concepts and learning science as inquiry, we embarked on the current study with the aim of measuring the impact of laboratory (hands-on and virtual) interventions on achievements in chemistry content test. We also compared post-test achievement scores for the two groups of preservice teachers (control/traditional and experimental/virtual).

RESEARCH METHODOLOGY

The baseline study followed a quantitative research methodology, as data was mainly numerical in nature (Leedy & Omrod, 2014). An experimental design was adopted, in which the sample of fifty preservice science teachers (n=50) were randomly selected from a group of 102 (N=102) third year preservice science teacher at a higher institution of learning.

Sample and data collection

In the first phase of the study, all fifty participants were given a chemistry content test (content validity established by a team of three expert science teachers), which assessed the understandings of atoms (isotopes and mass number), acid-base solutions, chemical reactions and the investigation of Beer's law (see Appendix A). After the test was marked and the scores recorded, participant preservice teachers were then separated into two groups through random sampling with the use of statistical tables. Twenty-five (25) participants were selected for the control and experimental groups respectively.

In the second phase, all participants engaged in a five-week intervention program. The control group was assigned to explore the chemistry concepts assessed in the pretest, within a hands-on chemistry laboratory, while the experimental group was assigned for the same period of time to online open PhET simulation laboratories to explore the same concepts. A two-day gap period was given to participants after the laboratory interventions were concluded. The same content test was again administered to the participants, marked and scores recorded. Both pre- and post-test scores were captured on IBM SPSS 25 and analysed using descriptive and inferential statistics. Figures 1 and 2 show sample screen shots of specific activities and links for virtual laboratory experiments, which the experimental group engaged in.

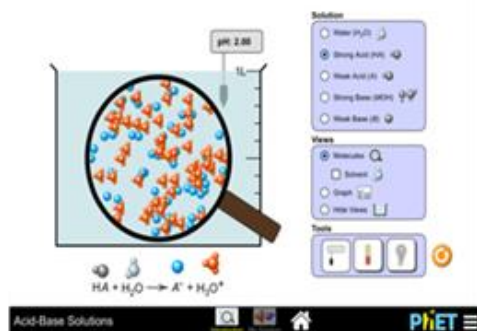


Figure 1: PhET simulation screenshot for learning acid-base solutions (University of Colorado, 2018).

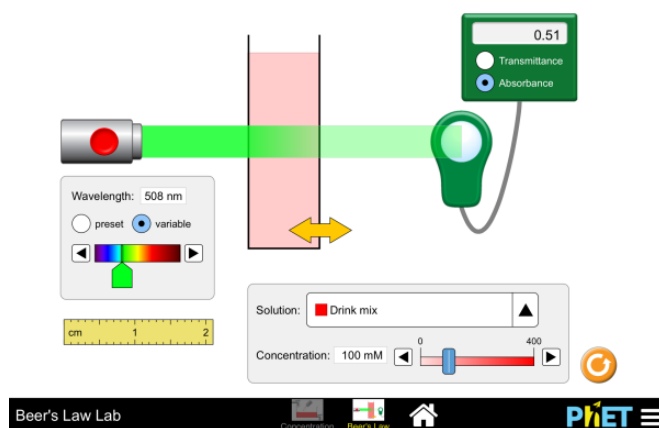


Figure 2: PhET simulation screenshot for investigating Beer's law (University of Colorado, 2018)

Research questions

The main research questions, which guided the inquiry, included;

1. What are the effects of laboratory learning on achievement in chemistry content tests?
2. How do post-intervention achievement scores compare for control and experimental groups?

Hypothesis

Ho1: There is no difference in content test achievement scores Pre and Post laboratory learning interventions for all pre-service teachers.

Ha1: There is a difference in content test achievement scores pre and post-test learning interventions for all groups of students.

Ho2: There are no differences in the post-intervention achievement scores for control and experimental groups of pre-service science teachers.

Ha2: There is a difference in the post-intervention achievement scores for the control and experimental groups of pre-service teachers.

Data analysis and results

Test scores from the study were analysed using SPSS 25. Descriptive statistics and results from independent sample t-test (after normality was established) were used to make the relevant conclusions. Table 1 shows the group descriptive statistics. As shown on the table below mean scores for pre-test (M = 60.20, S.D = 9.66) and (M = 60.72, S.D = 9.42) for control and experimental groups respectively where lower than the mean test scores for post-test (M = 68.72, S.D = 9.08 and M = 79.36, S.D = 8.31) for control and experimental groups respectively.

Table 1: Group statistics for pre-test and post-test scores for all groups

	Pre-Service teacher group	N	Mean	Std. Deviation	Std. Error Mean
Test scores for chemistry content test pre lab experience	Control group	25	60.20	9.657	1.931
	Experimental group	25	60.72	9.423	1.885
Test scores for chemistry content test post lab experience	Control group	25	68.72	9.076	1.815
	Experimental group	25	79.36	8.306	1.661

With the difference observed between the pre and post-test means, paired sample t-test was used to establish whether this observed difference between the pre and post-test means of the whole sample was significant at 95% confidence levels. Table 2 below shows the result of the paired sample statistics for the entire sample n =50.

Table 2: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Test scores for chemistry content test pre lab experience	60.46	50	9.446	1.336
	Test scores for chemistry content test post lab experience	74.04	50	10.150	1.435

As seen in Table 2, the mean post-test score for the entire sample ($M = 74.04$, $SD = 10.15$) was higher than the mean pre-test scores of the sample ($M = 60.46$, $SD = 9.44$).

Table 3 shows the result of the paired sample t test indicating statistically significant difference between pre-test and post-test scores for all the participants within the study $t(49) = -10.01$, $p < .01$).

Table 3: Paired sample t-test

		Paired Differences					t	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Difference			
					Lower	Upper		
Pair 1	Test scores pre lab experience Test scores Post lab experience	-13.58	9.592	1.356	-16.306	-10.854	-10.01	.000

In answering the second research question, on how post-intervention achievement scores compare for control and experimental groups an independent sample t-test (Levene's Test for Equality of Variances) was conducted to establish whether there was any significant difference between post-test scores for the two groups. The test revealed a statistically significant difference between the post-test scores for the control and experimental groups, $t(48) = 4.32$, $p < .01$). The mean content test score for the experimental group ($M = 79.36$, $SD = 8.306$) being significantly higher than the mean content test score of control group ($M = 68.72$, $SD = 9.076$), as shown on Table 4.

Table 4: T-test for group post-test scores

		F	Sig.	t	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Test scores for chemistry content test Post lab experience	Equal variances assumed	.209	.649	4.324	.000	-10.640	2.461
	Equal variances not assumed			4.324	.000	-10.640	2.461

DISCUSSIONS AND CONCLUSIONS

Based on the findings of this study, laboratory-learning interventions are proven to have a positive effect on achievement in chemistry content test. The extent of this effect was not included within the scope herein. In addition, the use of virtual laboratories in learning chemistry concepts proved to enhance higher conceptual understandings of the concepts than the use of the traditional hands-on laboratory, as revealed by the significant difference in the post-test scores for the control and experimental groups. These findings concur with the findings of recent studies which have been conducted using different virtual laboratory settings including, (Abdillahi Hajiomer, 2015; Estapa, & Nadolny, 2015; Hsu, et al, 2017). These researchers report that virtual laboratory learning had a positive impact on learners' understandings of scientific concepts and stimulated interest in science subjects. However, some of them noted that, learners did not connect with the authenticity of virtual laboratory spaces (Hsu, et al, 2017). Arvind & Heard, (2010) also reported that, the use of virtual laboratories simplified complex physics concepts and changed student's negative perceptions of the physics course. Similarly, Tüysüz (2010) reported that students who were comfortable in using virtual laboratories, showed a more positive attitude towards learning chemistry concepts. Contrary to these findings, a study reported by Payne, (2005) reported that 53% of the participant students did not endorse virtual learning at all. Other downsides of virtual learning registered include the lack of authenticity as reported by Hsu *et al.* (2017). For the current study, the authenticity of the simulators was also one of the aspects, which was not very appealing to the pre-service teachers.

Implications

The implications, which emanated from the findings of this preliminary study, are directly linked to the positive impact of laboratory (virtual or traditional) learning on learners' achievements in science content tests. Virtual laboratories proved to have a more positive impact on these achievement scores. Science teachers should therefore consider using virtual laboratories for teaching abstract concepts in all science subjects. Though virtual laboratories cannot replace hands-on laboratories, they are capable of complimenting them when learning abstract chemistry concepts and promoting higher achievement scores in content test. Curriculum experts should also consider situating the use of these virtual laboratories in science curricular globally.

Limitations

The current study reports the findings of a preliminary study with a relatively small sample size. Based on the sample size we cannot make any generalisations from the findings. We therefore recommend that a design-based research using mixed research methodologies, be done on a larger scale, to shed more light on the role of virtual laboratory spaces in science teaching and learning. Only four chemistry Concepts were exploited for the study and therefore we cannot assume that the experiences will be the same for all science subjects and concepts.

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THE RHIZOMIC DEVELOPMENT FROM STEM TO STEAM EDUCATION: USING PUPPETRY IN LIFE SCIENCES

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ABSTRACT: Decolonisation of the curriculum remains one of the most debated topics in the South African education landscape. In this paper, we debate the use of Indigenous Knowledge (IK) as a vehicle to facilitate the epistemological border-crossing from Science, Technology, Engineering and Mathematics (STEM) education to Science, Technology, Engineering, Arts and Mathematics (STEAM) education. Both the Nature of Science (NOS) and the Nature of Indigenous Knowledge (NOIK) comprises the tenets that it is empirical, inferential, tentative, subjective and creative in nature. However, in traditional school science the empirical nature of science is often emphasized, at the expense of its creative characteristic. Fundamental to the NOIK, in addition to its sometimes metaphysical nature, is its creative disposition, e.g. the emphasis on oral traditions such as storytelling. Tapping onto this tenet of the NOIK, student-teachers (STs) were exposed to puppetry as pedagogy to infuse arts into STEM education. This exposed them to the creative and subjective tenets of the NOS, which make this border-crossing possible. This qualitative study shows that most of the STs perceived puppetry as valuable in teaching science, but more so in the primary school. Third generation Cultural-Historical Activity Theory was used as an analytical lens to analyse data and identify tensions in the activity system.

Keywords: Indigenous knowledge; puppetry; science teacher education; cultural-historical activity theory.

INTRODUCTION AND PROBLEM STATEMENT

According to the Council of Higher Education, the decolonisation of the curriculum is at the heart of larger social and educational questions such as the prevailing social and power relations and a legacy of inequality that students saw as not having been dealt with in post-apartheid South Africa (SA) (de Beer & Petersen, 2016). Besides open access to all tertiary education institutions, many students still feel disenfranchised (Disemelo, 2015). In this regard, de Beer and Petersen (2016) argue that although all students have physical access to universities, they do not necessarily have epistemological access to the subject content matter, and this might contribute to the poor performance of many students. Debates regarding the decolonisation of the curriculum are mostly conducted from an ideological perspective which can be divisive and contribute to polarising the citizens of SA along racial lines. We agree with the current debates on the decolonisation of the curriculum, but advocate that we approach this matter from an educational perspective in order to improve epistemological access where students can identify with the content taught. Therefore, we argue that STEM education should be taught from a context-sensitive perspective, a concept that Gibbons (2000) called 'Mode 2 knowledge production'. We debate the use of IK as a vehicle to make the epistemological border-crossing possible from STEM to STEAM education by including puppetry as pedagogy. The 'A' in STEAM refer to arts, an approach to teaching to infuse arts in making STEM education more accessible to students. The research question that directed this research was: How do the STs perceive IK as a vehicle to make the epistemological border-crossing possible from STEM to STEAM education by using puppetry as a creative pedagogy? We argue that if we empower STs with skills to infuse arts in STEM education, they will be in a better position to include STEAM education in their pedagogy which might contribute in developing a new generation of science learners who will enjoy learning science. Such an approach will also sensitise learners to current

debates and challenges in society in order to find solutions to the problems society faces in the 21st century (Sousa & Pilecki, 2013).

CONCEPTUAL FRAMEWORK

According to Schwab (1964), Natural Sciences (hereafter referred to only as “science”) is, in essence, an investigative discipline in which inquiry and, exploration play a vital role. As a science, the South African Life Sciences (LS) school curriculum advises using teaching-learning methods which is more empirically based, to help learners understand the current body of LS knowledge (DBE, 2011). We can refer to STEM education where scientists primarily use the scientific method of investigation to provide answers about the natural phenomena around them (Mentz & de Beer, 2017). According to McComas (1998), one myth of doing science is that a general and universal scientific method exists but he argues that there is no single method applied by all scientists universally. By only using the scientific method during STEM education, the danger may occur that learners do not understand the true NOS. One perspective on the NOS acknowledges that science, as a body of knowledge, is based on facts, laws and theories, but it also recognises the role that human activity plays in investigations and processes (Abd-El-Khalick, Bell and Lederman, 1998). McComas (1998) argue that scientists base their work on imagination, prior knowledge, creativity, and perseverance. Cronje (2015) alerts to another aspect of the NOS, namely that it is a human endeavour that is affected by a social and cultural milieu. In the context of this paper, the concept “NOS” will be used according to the tenets of NOS as described by Abd-El-Khalick, Bell and Lederman (1998). Although these authors recognise the empirical nature and objectivity of science, they also include the creative tenets of the NOS where scientists also use their imagination in observations and experiments.

A study conducted in Limpopo Province (South Africa) found that the majority of the participating science teachers had an inadequate understanding of the NOS. Teachers follow mostly recipe-type practical work where learners are trained to follow the steps of the scientific method (de Beer & Ramnarain, 2012). Sousa and Pilecki (2013) claim that the outcomes of these types of experiments are already known to the learners and it is hardly a challenge or encouragement for these learners to be creative. Learners were able to memorise the facts and report on the data, but were unable to explain the findings, had little or no understanding of the scientific principles because their scientific thinking was obviously not nurtured (Sousa & Pilecki, 2013). Based on the findings of these studies stated above, we argue that school learners will have an inadequate understanding of the NOS as they were not exposed to all the tenets of the NOS.

People have many stereotypes about scientists and artists, one of which is that scientists are logical, analytical and precise individuals and make use of only convergent thinking. Another opposing stereotype is that artists can be regarded as creative, holistic and visual individuals only using divergent thinking. These stereotypes are a fallacy, as scientists can be creative and artists can be logical (Sousa & Pilecki, 2013). These stereotypes held by science teachers extinguish the creativity of their learners (Sousa & Pilecki, 2013). Research (Zimmerman, 2016) indicates that these practices are a result of many science teachers that do not possess a nuanced understanding of all the tenets of the NOS, as they focus largely on the tenets that the NOS is evidence-based, inferential and objective. In this paper, the authors posit that stereotypes like these can only be eradicated through effective science teacher education where STs are trained and exposed to doing science using all the tenets of the NOS as described by Abd-El-Khalick, *et al.* (1998). To address the imaginative and creative aspects as tenets of the NOS, STs were exposed to puppetry as a pedagogy to assist in the border-crossing from STEM to STEAM education.

A science teacher should design STEAM learning experiences where learners can use both ways of thinking during the learning activity. Using divergent thinking the learner can use his/her creativity to generate different ideas and ways to solve a problem. While breaking down the problem he/she

may gain new insights into the science content. However to come up with a solution to the problem the learner needs to use convergent thinking to put the different parts together. During such a teaching-learning activity the learners higher-order thinking skills will also be developed (Sousa & Pilecki, 2013).

We report on how IK and puppetry were used as vehicles to make the border-crossing between STEM to STEAM education possible. Both science and IK are empirical in nature, tentative, inferential, creative and culturally based. However, IK also has a metaphysical component (Cronje, 2015). According to Brits, de Beer and Mabotja (2016), storytelling and drama, can be used as an engaging pedagogy, in teaching Life Sciences, by dramatising science activities. These authors argue that drama has pedagogical benefits as it can create learning environments that will appeal to the affective domain of teaching and can lead to learning that is committed to long-term memory. The value of using puppets in entertainment is not questioned, and even the use of puppetry in the pre-primary and primary school is not disputed. However, the use of puppetry as pedagogy in the secondary school, and even at the tertiary level is considered with suspicion and not considered as “main-stream” in science education (de Beer, Petersen & Brits, 2018).

The use of puppetry as a pedagogy holds many advantages for learners. Puppets can help learners to express their self-assertiveness, physical balance, ability to communicate with others, and in the process contribute to their psychological development (Boueini, 2015). The Nuffield Foundation (England) initiated a puppetry project to help teachers to create more opportunities for productive conversations in the science classroom, in order to challenge learners’ ideas and to promote conversations in science (Keogh, Naylor, Maloney & Simon, 2008). Brits et al. (2016) argue that puppets can be used to teach controversial issues such as IK in Life Sciences. The reason for this claim is that learners may possess deep seeded prior knowledge or beliefs about these topics, in many instances linked to their religion and culture (Brits et al., 2016). These authors argue the use of puppetry could provide a good opportunity for teachers to build on prior knowledge to provide more “contextualized” or Mode 2 science knowledge (Gibbons, 2000). Introvert learners may express their opinions on controversial issues more readily if they identify with the problem of the puppet character and use it as a shield to hide behind (de Beer et al., 2018). Puppets can be used to create a distance between the self and the issue under discussion and contribute in creating a safe environment where students can express themselves and in the process develop their self-assertiveness and ability to argue and defend their point of view (Brits, et al., 2016). De Beer, et al. (2018) argues that through puppetry, students’ emotions will be part of the learning and could assist in conceptual change. Puppets can therefore also be used as a type of scaffold in the ZPD to take the learner from their actual level of development to their potential level of development (Brits, et al., 2016).

THEORETICAL FRAMEWORK: SOCIAL CONSTRUCTIVISM

This research is underpinned by social constructivism as a theoretical framework. Student teachers’ professional development was scaffolded across the zone of proximal development (ZPD) as described by Vygotsky (1978). Third generation cultural-historical activity theory (CHAT), as described by Engeström (1987), was used as an analytical lens for this research. Engeström (1987) focused on the main activity, which he called the activity system (AS). An AS consists of different elements, namely: the subject referring to the group, individual or system under examination; the object can be considered as the goal to be accomplished; the tools used for mediation during the activity; the community representing all the role-players in the activity; the rules that guide the involvement of the community during the activity; and finally the division of labour which identifies which roles the different members might fulfil in executing the activity (Figure 1). Figure 1 depicts two sub-activity systems where the different elements are customised where STEM and STEAM education are the subjects. As an example, the object in the STEM sub-activity system is the focus on

the empirical, tentative and inferential tenets of the NOS, in contrast to the object in the STEAM sub-activity system which also includes the creative and subjective tenets of the NOS. Figure 1 depicts the descriptions of the other elements relevant to this study.

CHAT was chosen to explore the perceptions of fourth year Life Sciences STs using IK and puppetry as pedagogical vehicles to enable such epistemological border-crossing from STEM to STEAM education. CHAT, in essence, is based on a Vygotskian view of learning who suggested that higher order cognitive development occurred with the mediation of cultural tools, signs and artefacts during social interaction (Veresov, 2010). Vygotsky (1978) suggested that learning take place on two levels: first on a social plane, and secondly on a personal plane where learning is internalised. This means that learning takes place in association with others in a specific socio-cultural context and is therefore not an isolated event (Stetsenko, 2010). According to Vygotsky, there is an inherent ‘zone for development’ that the subject in the AS participates in using scaffolding to achieve an objective. Scaffolds can be regarded as appropriate support mechanisms that a facilitator can provide to help the subject to reach the goal (object) of the activity in the ZPD. CHAT can be used in one of three ways, on a personal plane, an interpersonal plane or an institutional plane (Mentz & de Beer, 2017). In this paper, CHAT will be used on an institutional plane (Mentz & De Beer, 2017) where the subject is a system or theory and not a person. Two sub-activity systems, namely STEM education and STEAM education (Figure 1) will be compared while the complexities of the ‘objects’ of the two activity systems will be stressed and in the process illuminating the ‘contradiction of control’ (Mentz & de Beer, 2017) between the two objects.

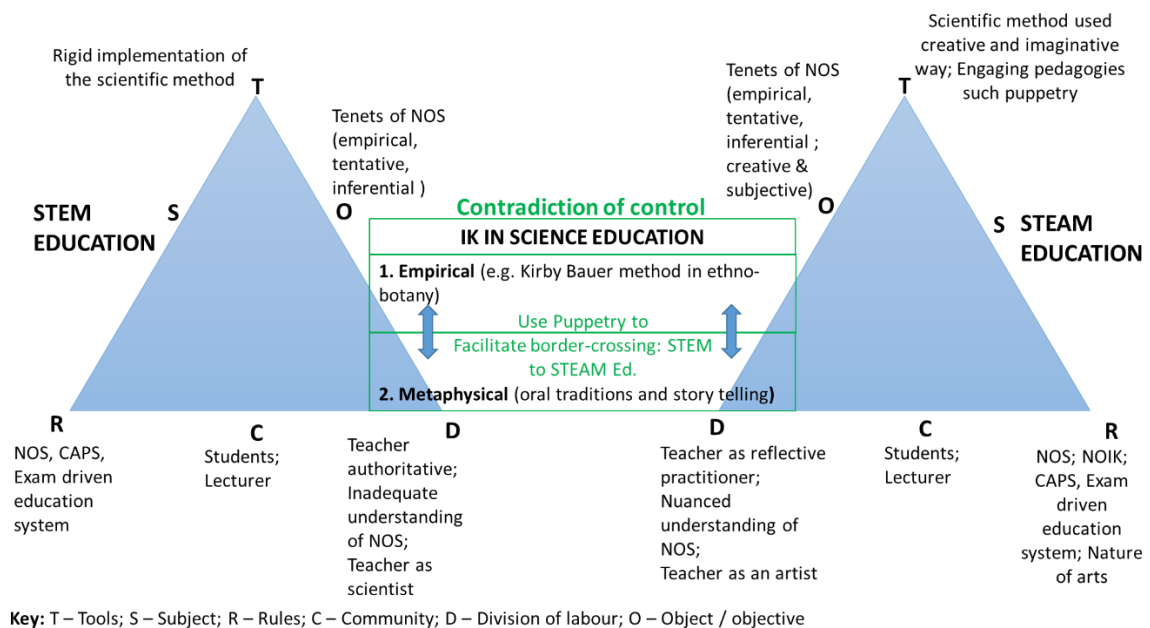


Figure 1: CHAT on an institutional plane: Comparing STEM and STEAM education (adapted from de Beer & Mentz, 2017)

According to Mentz and de Beer (2017), CHAT can be used as a barometer of tensions in the AS. Engeström (1987) distinguish four levels of tensions. These tensions range through levels which can occur within each constituent of an activity (level 1) to tensions between different ASs (Level 4). Engeström (1987) argues that ASs are built around its objects. Inherently between two sub-activity systems is the complexity of its objects (McNeil, 2013) but a “unified or shared objective” is not always present in an activity system” (Mentz & de Beer, 2017). Based on the complexities of the objects of AS, McNeil (2013) refers to the “contradiction of control” that exists in AS.

METHODOLOGY

A qualitative study, within an interpretive paradigm, was used to explore the perceptions of Life Sciences STs on the use of puppetry as pedagogy. A purposive sampling method was used as only Life Sciences STs were exposed to puppetry in Life Sciences teaching as part of their prescribed methodology course. Data were collected through open-ended pre-questionnaires to explore their views on puppetry. STs were then exposed to a short PowerPoint lecture which addressed both the tenets of the NOS and the use of puppetry as pedagogy in a LS classroom. The lecture was followed by a puppet show where two puppets (a scientist and a school learner) discussed IK as an alternative to western medicine. This served as an introduction to the lesson.

STs, then, engaged in cooperative learning. De Bono's hats as teaching method were used where STs explored the possibilities of using puppets as one of their teaching-learning methods in their future teaching careers. This allowed them to take both negative and positive aspects into consideration. An open-ended post-questionnaire was completed after the lesson to determine whether their views have changed on the use of puppets as pedagogy. In addition to this, STs had to submit an assignment which included a short script, infusing IK into LS and puppet show which was videotaped. Reflective notes on their experiences on the production of the puppet show were also required. Data were transcribed and analysed and codes were assigned to similar concepts which became evident from the data. Codes were then organized into themes according to Saldaña's (2013) method.

Ethical considerations were taken into account as STs was informed that the particular lesson was also being used for research purposes. Although they were assured that they were under no obligation to complete the questionnaires, they were informed that they still had to participate in the activities as it formed part of the outcomes of their curriculum. All STs gave their voluntary informed written consent after the purpose of the research project was discussed with them. They were assured that all data would be treated confidentially and that their identities would not be disclosed.

FINDINGS

This paper reports on research which is still in its initial phase. As CHAT is a barometer of tensions, the following tensions were identified within this AS. Firstly tensions existed between the rules and the object. STEAM education incorporates arts into teaching but due to the restricted nature of the CAPS document (DBE, 2011), where teachers have to adhere to time frames indicated in the document, STs were of the opinion that there will be insufficient time to incorporate puppetry as pedagogy and that introducing puppetry as pedagogy will be very time consuming and will require more work from the teachers. The CAPS document also reflects an exam-driven system and the perceptions of STs were that puppetry will not be suitable to portray the factual content of the examinations. Secondly, tensions were apparent between the community and the tools. Perceptions of STs were that LS are more empirical in nature which addressed STEM education, and did not sufficiently acknowledged the tenets of NOS such as its subjective nature, creativity, and that science is socially and culturally constructed. This finding is consistent with the research of De Beer and Ramnarain (2012). Student teachers also believed that puppetry as pedagogy was not suitable for learners in the secondary school and would be a more appropriate strategy for younger learners which supported the research findings of De Beer, Petersen and Brits (2018). Comments such as "learners might find puppetry childish", "learners will make jokes and may therefore disrupt classes", were concerns that STs mentioned when they were exposed to puppetry as a pedagogy.

CHAT also illustrates tensions between sub-activity systems. This was evident in the contradiction of control between the two sub-systems. In STEM education teachers rely heavily on the scientific method in LS but in STEAM education creativity is addressed (Keane & Keane, 2016) as one of the

tenets of the NOS (Abd-El-Khalick, *et al.*, 1998). Feedback from the STs indicated that they had different opinions on using puppetry as pedagogy to infuse IK into science themes. On the one hand, some STs indicated that puppetry is an innovative, creative and exciting strategy to make learning fun, meaningful and stimulate the affective domain of the learners. On the other hand, STs felt that puppetry was not suitable to address topics in LS as it is more scientific in nature. This refers to “contradiction of control” as McNeil (2013) indicated, as STs who will be willing to incorporate the subjective tenets of the NOS will plan creative lessons when they become teachers but the creative element will be omitted if STs view LS purely as empirical in nature.

In Figure 1 it is shown how puppetry could provide a “bridge” in the epistemological border crossing between the two seemingly conflicting sides of IK. Indigenous knowledge has a strong empirical side to it, and authors such as de Beer and Whitlock (2009) show how learners could engage with IK utilising the “tools” of science. These authors show how a Kirby Bauer technique could be used in the science classroom, to test the anti-microbial properties of medicinal (muthi) plants. However, such activities do not address the holistic NOIK, as IK also has a metaphysical character. This metaphysical aspect could also be addressed in the science classroom, by engaging in puppetry, where learners can discuss whether certain aspects of IK should be seen as pseudo-science.

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SYSTEMIC PRESSURES – CUTTING THE WINGS OF LIFE SCIENCES TEACHER DEVELOPMENT

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ABSTRACT: In July 2017, a short-learning programme (SLP) was held to help Life Sciences teachers integrate Indian indigenous knowledge (IK) into the curriculum. After this two-day intervention, teachers were motivated to include aspects of Ayurveda (Indian IK) in their lessons. Data gathered through subsequent class visits (using RTOP), portfolios and lesson plans, showed, instead, that the systemic pressures amidst the stark realities of the school situation curbed their enthusiasm to implement what they had gleaned from the SLP. This paper uses the research lens of Cultural-Historical Activity Theory (CHAT) to analyse the data collected and compare two interdependent activity systems that arise, namely, the intervention itself, and the post-intervention classroom. A contradiction of control (in terms of the 'object' in the activity system) emerges from this comparison that shows a dissonance between the intended outcomes of the intervention with the actual implementation (transfer) in the classroom afterwards, and will be explored in this paper. Although much of the data gathered showed a failure from teachers to infuse indigenous knowledge into the curriculum, one teacher was able to successfully integrate aspects of IK into his lesson, thus confirming the existence of keystone species in the community of practice to inspire other teachers to improve their teaching.

Keywords: Indigenous knowledge; Ayurveda; systemic pressures; Cultural-Historical Activity Theory; nature of science; nature of indigenous knowledge; pedagogical content knowledge

INTRODUCTION

Ongoing teacher development is crucial for improving learner performance in South African schools. Thus, a two day short-learning programme (SLP) was held in the predominantly Indian suburb of Lenasia, South Africa in July 2017. The focus of this SLP was to introduce Life Sciences teachers to several inquiry-based strategies that they could use in their lessons to infuse indigenous knowledge (IK) with particular emphasis on Indian IK (Ayurveda) into curriculum themes. The focus of this paper is not on Ayurveda as such, but in order to provide the relevant context, it might be necessary to briefly describe Ayurveda. This Sanskrit term means 'the science of life', and it is a 5000-year-old Indian healing system, that aims to treat the patient by determining the root cause of the illness, and not the symptoms of the disease like allopathic medicine does (Reddy, de Beer & Petersen, 2017). Although the SLP was a success, the subsequent implementation in classrooms was not. This paper intends to use CHAT as a research lens to explore possible reasons for why the SLP's did not have the desired outcome.

Theoretical Framework and CHAT

The theoretical framework is social constructivism, and how teacher professional development could best be scaffolded across the zone of proximal (teacher) development (Vygotsky, 1978; Warford, 2011). The Cultural-Historical Activity Theory (CHAT) was devised originally by Vygotsky (1978) and later modified by Engeström (2011) into a third generation activity theory. CHAT is used, as a research lens to examine the tensions that arose when teachers failed to implement the ideas learnt at the SLP. This paper is based on the notion that IK is an important part of the Life Sciences curriculum and that Indian IK can be included in the curriculum while foregrounding the pressures imposed by the educational system that could prevent this inclusion.

CHAT has six aspects or ‘nodes’ (tools, subject, rules, community, division of labour, and object) inter-connected by two-way arrows to show the dynamic relationship between each aspect to achieve a specified outcome (Hardman, 2008). Together, they form an activity system which is the unit of analysis for the researcher. Mentz and de Beer (2017, p. 90) believe that it is also possible and preferable to juxtapose two activity systems in order to provide deeper insights into more complex issues facing education and teacher development in SA (p. 92). They support Engeström’s view that since we live in an interconnected world, it is more useful to consider a minimal unit of analysis as two interdependent activity systems. This paper will therefore use two interlinked activity systems to illustrate the contradiction between teacher intervention (Activity System A) and teacher implementation in the classroom (Activity System B) (see Figure 1).

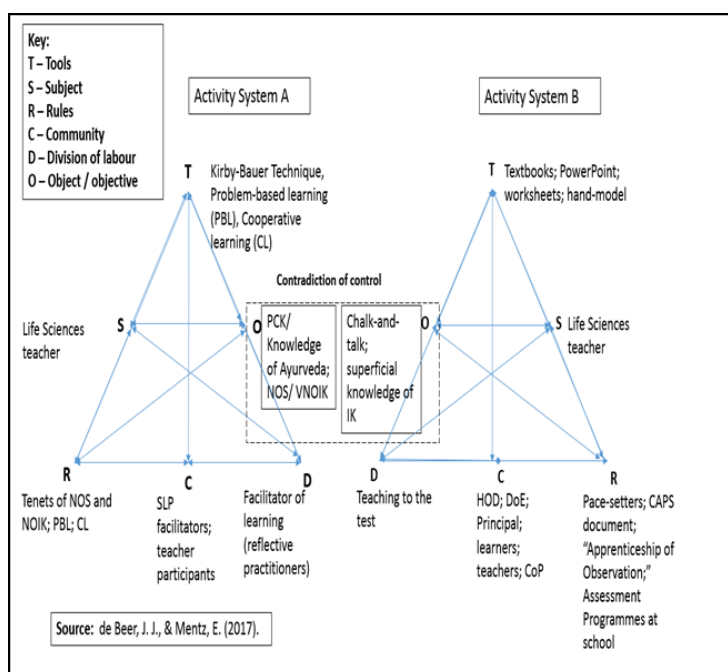


Figure 1: Contradiction of control between two juxtaposed activity systems

Activity System A represents the two-day SLP (as activity system) where the Life Sciences teacher participant is the SUBJECT who was part of a COMMUNITY consisting of the facilitators of the SLP and other teacher participants. The course facilitators used TOOLS such as the Kirby-Bauer technique; problem-based learning (PBL) and cooperative learning (CL) strategies in order to inform teachers about Ayurveda; the nature of science (NOS); and the views of the nature of IK (VNOIK) – all in an attempt to increase their pedagogical content knowledge (PCK) – thus forming the OBJECT of the activity system. During the SLP, certain RULES had to be adhered to as set out by the tenets of the nature of science (NOS); tenets of indigenous knowledge (NOIK); the fundamental principles of PBL and CL. The DIVISION OF LABOUR in this activity system was achieved by the SLP presenters who encouraged the participants to become reflective practitioners.

Activity System B is a mirror-image of Activity System A and depicts the classroom implementation of techniques learnt at the SLP by some of the teacher participants. In this case, the common feature is the SUBJECT which remains the Life Sciences teacher, although in this case in the classroom context. The teacher is now governed by a different set of RULES laid down in pace-setters (issued by the Department of Basic Education), curriculum documents (CAPS), assessment programmes of the school, and an interesting phenomenon known as the “Apprenticeship of observation” described by Lortie (1975) and cited in Mewborn and Tyminski (2006, p. 30). This will be explained in Section 4.

The DIVISION OF LABOUR in the classroom situation is achieved by the need for teachers to ‘teach to the test’ where lessons centre on training learners to write examinations. The COMMUNITY in this case, is made up of the school management, other teachers in the Life Sciences department, the community of practice in which the teacher fits, and the Department of Education. TOOLS include textbooks, Power Point slides, whiteboard, and a hand-model as a learning aid in one classroom observation. The OBJECTIVE of this Activity System is the chalk-and-talk method of teaching and a superficial knowledge of IK that the teachers displayed. Comparing the OBJECTIVES (or ‘OBJECTS’) in each activity system shows that they are in conflict with each other resulting in a contradiction of control (McNeil, 2013, cited in Mentz & de Beer, 2017, p. 95).

This dissonance between the intended aims of the SLP with the actual implementation in the classroom necessitates the use of CHAT as a lens through which to analyse these interdependent activity systems. It is also necessary to examine briefly, other concepts relevant to this study, viz. IK, including Indian IK, the NOS and the NOIK, and the systemic pressures placed on schools by the Department of Basic Education (DBE).

Indigenous Knowledge Systems (IKS) and Ayurveda

Odora-Hoppers (2005, p. 2) describes IKS as the “sum total of the knowledge and skills which people in a particular geographic area possess, and which enables them to get the most out of their natural environment.” The relevance of IK integration into the school Life Sciences curriculum has been dealt with in detail by many researchers. For instance, de Beer and Whitlock (2009, p. 198) explain that when students’ cultures and social identities are acknowledged in lessons, it makes the learning experience more positive for them.” South Africa is a multi-cultural country and includes the minority Indian population originally brought by the British from India as indentured labourers to cultivate sugar-cane during the 1800s. Indian children make up a fair part of many classrooms in South Africa but their IK, such as Ayurveda, is not included in the current Life Sciences curriculum, which focuses instead, almost exclusively on African IK. During the SLP, participants were given substantial information on Ayurveda with particular relevance to the curriculum to make integration into lessons easier, thereby hoping to increase the PCK of teachers. Details about the Ayurveda content covered during the SLP have been dealt with in a previous paper (Reddy et al, 2017) and will not be repeated here.

Teacher development and Pedagogical Content Knowledge (PCK)

PCK refers to teachers’ subject matter knowledge, the skill of teaching it to learners so that they understand the content; and the capacity to use resources or improvise when resources are unavailable to enhance this understanding (Shulman, 1986). For the successful integration of IK into their lessons, teachers should pursue activities to enhance their PCK as one of the objectives, this is depicted in Activity System A (Figure 1). One such activity is attending SLP’s such as the one held in Lenasia and then implementing what was learnt in their classroom. Teaching is a dynamic practice that requires teachers to remain life-long learners if they want to make a lasting difference in society (November, 2015, p. 336). It is then necessary for teachers to continuously explore and engage in professional development activities. Gravett and De Beer (2015, p. 3) share this idea that good teachers who realize they cannot learn everything about teaching from a single teacher training programme must engage in ongoing teacher development. In South Africa, teacher development is critical, since the education system has been pronounced as “unequal, inefficient and underperforming” (Spaull, 2012 in November, 2015, p. 321). One of the ways in which the most recent curriculum document (CAPS) tries to address these criticisms is by giving indigenous knowledge (IK) more prominence (DBE, 2011, p. 17). According to November (2015, p. 330), IK is an important means of empowering communities to combat social problems such as marginalization and poverty. The intention of the SLP was therefore to afford teachers an opportunity to develop

their PCK around IK while also serving as a catalyst that would stimulate a continued search for other ways of enhancing their development as teachers.

Nature of Science (NOS) and the Nature of Indigenous Knowledge (NOIK)

The **NOS** is defined by Vhurumuku and Mokeleche (2009, p. 97) as “the individual (psychological) and socially mediated understandings, beliefs, values, assumptions, views, images, and perceptions of the products and processes of science.” One of the seven tenets of the NOS that is relevant to IK is that science is socially and culturally embedded. The **NOIK** emerged as a result of helping teachers to successfully integrate IK into their science lessons (Cronje *et al*, 2015, p. 322). These researchers have effectively summarized a set of tenets that may be aligned to the tenets of the NOS. There is also a social, collaborative and cultural tenet that is similar to the tenet stated for the NOS. Teachers also need to have sufficient knowledge about the NOIK which will contribute to their PCK and enable them to enhance the integration of IK into their lessons.

Systemic Pressures in South African public schools

The present public school curriculum in South Africa is known as the Curriculum and Assessment Policy Statement (CAPS) which was introduced in 2012 (DBE, 2011). Anecdotal evidence during teacher-training workshops for CAPS implementation indicated the focus lay on completing content-laden curricula whether learners understood the content or not. The completion of content is driven by the dreaded “pace-setter” – a tool designed to ensure teachers taught a prescribed number of topics within strictly specified times during the term. Progress of the pace-setter is monitored and enforced by school management and education department officials whose main task is the quarterly regulation of curriculum coverage. This places undue pressure on teachers who are forced to completing content merely to comply with the Pace-setter rather than on learners’ cognition or performance. Compulsory mid-year provincial examinations based on the topics prescribed in the Pace-setter further exacerbate demands on teachers. This often results in ‘teaching to the test’ at a frenetic pace such that curriculum is covered merely for learners to write common assessments rather than to enhance learning. These and other systemic pressures on teachers provide the dissonance in the two activity systems shown in Figure 1, thereby leading to the Contradiction of Control between the two objectives.

METHODOLOGY

This was a qualitative research study that used CHAT as a research lens to analyse the data collected.

Sampling and Data-gathering Techniques

Since this was qualitative research, purposive sampling was used to select only Life Sciences teachers. It was anticipated that since the study involved Indian IK, holding the SLP in Lenasia would attract a majority of Indian teachers. However, twenty-three teachers of various race groups (Whites, Africans, Indians and Coloureds) eventually attended the SLP. Class visits were conducted a few months after the SLP, and teachers’ lessons observed using the Reformed Teaching Observation Protocol (RTOP) instrument (Sawada *et al.*, 2002) thereby avoiding the need to record the lessons by video or audio. Teachers observed were then interviewed briefly after the lessons and their responses transcribed. The interview protocol focused on the individual teacher’s experiences on infusing Ayurveda into the CAPS curriculum.

Ethical Issues

The teacher participants each filled out a permission form at the start of the SLP. No audio or video recordings were taken of the class visits to further ensure their privacy, confidentiality and anonymity at all times of the study. In the written consent to participate in this study, the respondents indicated that were doing so on a purely voluntary basis and that they could withdraw

at any time from the research without prejudice. Appropriate feedback will be given to them on the outcomes of the investigation once it is complete.

Data Analysis Method

Data was analysed using the coding method described by Saldaña (2009) where descriptor codes are assigned to the observations from the class visits and interviews. These codes were then clustered into categories which were in turn grouped into emerging themes. The coding process was guided by the focus of this paper which was to explore the extent to which teachers were able to implement the techniques learnt during the SLP and what factors inhibited implementation.

RESULTS AND DISCUSSION

The teacher participants responded to the SLP with excitement and a keen sense of wanting to find out more about Indian IK while also showing an eagerness to implement the various techniques to promote inquiry-based learning that they had learned from this intervention. Subsequent follow-ups by the researchers intending to visit these teachers to observe lessons were then met with reluctance and in some cases, phone-calls or emails from the researcher requesting class visits were ignored. Up to the writing of this paper, four class visits were done where three of them showed no IK integration whatsoever into their lessons.

After subjecting the data (brief interviews and class visits recorded on the RTOP tool) to Saldaña's coding method, the following provisional themes emerged:

- A) **Having the necessary expertise, qualifications and subject knowledge was insufficient to enable more integration of IK into the lesson.** The teachers were suitably qualified to teach Life Sciences ranging from a Bachelor of Science to a Masters in Science degree and were therefore used their PCK quite expertly to answer learners' questions while drawing them towards the topic under discussion. Apart from the one teacher who had an MSc and over 27 years of teaching experience, the other teachers observed were unable to use their existing knowledge and expertise to bring in the IK learned during the SLP. The other teachers stated that the topics they were teaching (Nervous System, Gaseous Exchange and Photosynthesis, respectively) were not suitable for the inclusion of IK. Had their PCK been more enhanced, they probably could have found ways of doing so. This also reflects on a lack of self-directed learning among them.
- B) **Most teachers struggle to incorporate IK into their lesson due to time constraints and a content-laden curriculum.** One teacher stated during the interview that "*Given a choice, I would infuse more IK to make the topic more relevant.*" The same teacher also laments that the "*curriculum is too packed to allow for much more infusion of IK.*" Another teacher mentioned time being a challenge facing teachers to integrate IK into the curriculum. However, he also realized that despite this, it would be up to the teacher to ensure it is taught in some form or the other. Having said this, it must also be stated that this teacher was able to successfully incorporate aspects of IK into his lesson on cancer by expertly drawing on learner inputs during the lesson. He could be seen as a "keystone species" among other Life Sciences teachers, serving to motivate and inspire them to be more creative in integrating IK into topics despite time constraints.
- C) **Regardless of teacher development programmes, many teachers continue to teach in the same manner in which they were taught.** This is based on Lortie's (1975) "apprenticeship of observation" where he surmises that teachers' practices are based on the imitation of their own teachers. This theme emerged from the observations due to traditional teaching styles used; resources; and the rigid arrangement of furniture in the classes. The teaching styles observed, all involved teacher-centred chalk-and-talk methods with none of the inquiry-style techniques demonstrated during the SLP. The resources used in all the lessons observed included textbooks; worksheets; Power Point slides and white-boards; and in one case, hand models (showing the parts of the brain). Except for the last three resources, all the others were probably also used

during the time when these teachers were learners themselves. The cinema-style seating arrangement was also the same as when these teachers were learners.

The RULES in Activity System B (Figure 1) were therefore governed by time constraints, apprenticeship of observation and the rules of the school where certain points in the Pace-setter had to be reached within a certain time to enable assessment to proceed. The NOS and NOIK were hardly ever included in any of the lessons observed. The TOOLS in each activity system point to different objectives: in Activity System A the focus is on inquiry-based learning whereas in Activity System B the emphasis is on completing syllabus. These instances show the Contradiction of Control emerging between the objectives in each Activity System. In this paper, this contradiction concerns the conflict between the intended outcomes during the SLP for improved teacher development with the actual implementation in the classroom primarily as a result of the systemic pressures facing South African public schools.

CONCLUSION AND RECOMMENDATIONS

Teachers indicated that time was short since it was more important to complete the curriculum to comply with departmental regulations rather than spending time on the different learning techniques shown at the SLP. Coupled with time constraints and the heavily-laden curriculum, Lortie's (1975) "apprenticeship of observation" played a significant role in limiting teachers' creativity in implementing the techniques learned at the SLP. CHAT provided the connection between the different nodes to shed light on the limitations. However, certain keystone species of teachers can be used to inspire other teachers to tap into their creativity to use inquiry-based methods and the integration of IK to ultimately enhance their lessons. Going forward, the curriculum should perhaps be trimmed and pace-setters made more flexible to allow more time to infuse IK into the lesson in order to comply with the CAPS document. The SLP designers should also look into more systemic and longitudinal support for teachers.

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STUDENTS' PERCEPTION OF THE PSYCHOSOCIAL AND PHYSICAL ASPECTS OF LABORATORIES

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ABSTRACT: A laboratory is a place where meaningful understanding of the subject unfolds. Thus a well-crafted laboratory can meet its objectives in terms of student success. The purpose of this study is to determine students' perception of such crafted environments through an evaluation of its physical and psychosocial factors. Such an evaluation is measured through two questionnaires; one called the "Science Laboratory Environment Inventory" (SLEI) and the other called the "Physical Science Laboratory Environment Inventory" (PSLEI). In particular, the physical and psychosocial aspects of different laboratories are the main focus of this study. Results reveal a positive attitude by students on many of the SLEI scales for most of the laboratories. In terms of the physical aspects, students have rated many of the PSLEI scales with a high degree of suitability for nearly all laboratories. Students have evaluated the physical aspects of the laboratories with a high degree of fitness than its psychosocial counterpart.

INTRODUCTION

A good quality classroom environment is important as it helps in shaping the students' emotion and attitudes towards the subject, their attitudes towards their classmates and the education system as a whole (Che Ahmad, Yahaya, Lee Abdullah, Noh & Adnan, 2015; Zedan, 2010). In particular, the laboratory classroom environment is a case in mention. The laboratory-learning environment in this case would play such a role in engaging students in laboratory activities that will promote a better understanding of scientific concepts and problem-solving skills. The net effect of this is that students will have a better attitude towards the subject (Arzi, 2003; Ozkan, Carikoglu & Tekkaya, 2006; Che Ahmad, Osman & Halim, 2014). The focus of this research is on the physical and psychosocial aspects of the laboratory. These factors, in particular are considered important in determining students' success in teaching and learning (Che Ahmad, Shaharim & Lee Abdullah, 2017). The physical aspects of the laboratory classroom environment include everything that can be seen, heard or touched and includes parameters such as Furniture and Equipment, Learning Space, Lighting, Interior Air Quality, Safety and Technological Equipment. On the other hand, the psychosocial aspects focus on the social systems whereby interactions between students, teachers and environment are important (Che Ahmad et al., 2015). According to Arzi (2003), laboratories with better facilities are associated with active forms of learning. This in turn will have an influence on the teacher-student communication levels and thereby result in better outcomes in the cognitive and affective domains of learning (Doorman, Fraser & McRobbie, 1995; Che Ahmad et al., 2014). However, a lack of such resources and facilities could have a detrimental effect on the student in terms of their concentration, mood, well-being, attendance and performance (Higgins, Hall, Wall, Woolner & McCaughey, 2005; Che Ahmad et al., 2014). On a positive note, a well-equipped laboratory with all the facilities could on the one hand encourage active forms of learning and on the other hand allow the teacher to diversify his/her pedagogical approaches to teaching (Che Ahmad et al., 2014).

Learning in the laboratory classroom environment must be regarded as an important component in Science Education (Kwok, 2015) and therefore the physical and psychosocial aspects of the laboratories must be evaluated regularly. Numerous studies have been done on learning classroom environments (Fraser & Walberg, 1991; Margianti, Fraser & Aldridge, 2001) and for which instruments have been developed and validated for that purpose. In South Africa, the laboratory classroom is an important room where good students of physics come together to do experimental

experimentation. In this respect, since much research has been on the psychosocial aspects of the laboratory and less on the physical aspects of the laboratory, hence the need for this research from a South African context. Further, most research is focussed on the perceptions of students from different classes on their perceptions of the laboratory classroom environment. In this context, our research will focus on a combination of the aspects (physical and psychosocial) and to the students' perception of these aspects with respect to different laboratories.

RESEARCH QUESTION

To what extent are the students' perceptions of the physical and psychosocial aspects of different laboratories to the satisfaction of the students?

CONCEPTUAL FRAMEWORK

The criterion as laid out by Moss (1979) & Doorman et al., (1995) which pertains to human environments was used as the conceptual framework for this study. They are as follows:

1. Relationship dimension (R): This dimension refers to the way people want to help and support one another.
2. Personal Dimension (P): This dimension refers to the extent the environment either promotes or stifles one's growth.
3. System Maintenance and System Change (S): This dimension speaks about the orderliness (or readiness) of systems, its expectations and its response to change.

The scales of Fraser, Giddings & McRobbie (1993) and that of Che Ahmad et al. (2014) are respectively, classified according to the schema of classification by Moss (1979). These are shown in tables 1 and 2, respectively. A description of the various scales of Fraser et al. (1993) and a description of the scales according to Moss's criteria is shown in Table 1:

Table 1: SLEI scale description with Moss's classification

Scale	Description (Kwok, 2015)	Moss criteria
Student Cohesiveness	The extent to which students help, know and support each other in the laboratory	R
Open-endedness	The extent to which an open-ended (or divergent) approach to experimentation is allowed	P
Integration	The extent to which laboratory activities are aligned to work covered in class	P
Rule Clarity	The extent to which rules about behavior is formalized	S
Material Environment	The extent to which the laboratories are equipped for experimental work	S

A description of the various scales of Che Ahmad et al. (2014) and a description of the scales according to Moss's criteria is shown in Table 2:

Table 2: PSLEI scale description with Moss classification

Scale	Description (Che Ahmad et al., 2014)	Moss criteria
Furniture and Equipment	The extent to which Furniture and Equipment are suitable for use in the laboratories	S
Learning Space	The extent to which Learning Space is adequate for experimental work	S
Technology	The extent to which ICT technology is available for both staff and students	S
Lighting	The extent to which Lighting in the laboratories is suitable for experimental work	S
Indoor Air Quality	The extent to which the Air Quality in the laboratories is suitable for experimental work	S
Safety	The extent to which the laboratories ensures Safety of both staff and students (e.g. availability of a fire extinguisher)	S

METHODOLOGY

In this study we have explored the students' perceptions of the physical and psychosocial aspects of the undergraduate physics laboratory at a South African university. As a quantitative study, use was made of two questionnaires for data collection. The first questionnaire, called the "Science Laboratory Environment Inventory" (SLEI). This questionnaire was developed and validated by Fraser et al. (1993) in six countries amongst 5447 high school students. The second questionnaire, called the "Physical Aspects of Science Laboratory Environment Inventory" (PSLEI) was developed and validated by Che Ahmad et al. (2014) amongst 800 high school teachers from 100 high schools. The SLEI questionnaire consists of 35 questions and 5 scales (each scale has 7 items) and they are as follows: Student Cohesiveness, Open-endedness, Integration, Rule Clarity and Material Environment. The PSLEI questionnaire consists of 28 questions and 6 scales (each scale has different number of items) and they are as follows: Furniture and Equipment (4 items), Learning Space (5 items), Technology (4 items), Lighting (4 items) Interior Air Quality (4 items) and Safety (7 items). Further, the SLEI consist of two forms; one form describes the students' actual (experiences) perception of the laboratory and the second form describes their preferred perception (ideal) of the laboratory (Kwok, 2015). It is mentioned by Fraser (1994), that a congruence between the actual and preferred perceptions is likely to have a positive effect on the students' attitudinal and cognitive learning outcomes (Kwok, 2015). A Likert-type scale of evaluation from Strongly Disagree (+1) to Strongly Agree (+5) was used to measure both perceptions of the laboratory environment. For the PSLEI questionnaire, only the Electricity, Mechanics and Thermodynamics laboratory was taken into consideration, while for the SLEI questionnaire, a further 2 laboratories were added to the list and they were the Optics and Kinetics laboratories. The reasons for the latter was to get a holistic picture of our laboratories. In respect to the physical aspects of the laboratories, most of them have a similar nature in layout. Permission to do this research was obtained from the respective authors as well as the facilitators and students that were at the respective laboratories at the time of the research. Results are expressed as mean values.

RESULTS AND DISCUSSIONS**Results and discussion of the Psychosocial aspect of the Laboratory Learning Environment**

The results of the actual and preferred data from the SLEI data are presented in Table 3:

Table 3: The average mean scores of the various psychosocial factors of the SLEI questionnaire for each of the 5 laboratories. The numbers in brackets indicates the number of students per laboratory

No	Scale	Actual/Preferred	Optics Lab(29)	Thermodynamics Lab (25)	Mechanics Lab (19)	Kinetics Lab (16)	Electricity Lab (31)
			Mean value	Mean value	Mean value	Mean value	Mean value
1	Student Cohesiveness	Actual	2.68	2.81	3.20	2.95	2.61
		Preferred	2.58	2.86	2.99	2.97	2.47
2	Integration	Actual	3.27	3.28	3.33	3.06	3.16
		Preferred	3.31	3.14	2.90	3.14	3.12
3	Open-Endedness	Actual	3.10	3.17	3.33	3.48	2.95
		Preferred	3.07	3.13	2.95	3.22	2.91
4	Rule Clarity	Actual	2.95	2.52	2.60	2.49	2.54
		Preferred	2.35	2.51	2.31	2.39	2.46
5	Material Environment	Actual	3.07	2.82	3.23	2.96	3.35
		Preferred	3.25	3.19	3.25	3.78	3.32

Psychosocial aspects between the Physics laboratories

Students have displayed a positive attitude towards most of the SLEI scales except for two scales, namely, Rule Clarity and Student Cohesiveness. The highest mean score was for the Integration scale, while the lowest mean score was for Rule Clarity. High mean scores for the Integration scale coincides with studies undertaken by Osman, Che Ahmad & Halim, 2011; Lilia, 2009 & Fraser and Lee, 2009.

The Material Environment actual scores for each of the laboratories appears to be aligned to the preferred scores, except for perceptions about the Kinetics and Thermodynamics laboratory where there appears to be huge discrepancies. This means that their expectation for equipment to be good working order is more preferred. Due to the overload of equipment in these two laboratories limits the working space of the students. During pre-laboratory sessions, student observation of teacher demonstration is obscured and the students view this negatively as it compromises their comfort levels in the laboratory.

There appears to be a close correlation between the actual and preferred mean scores on the Integration scale for most laboratories except for the Mechanics laboratory. Results reveal that, mostly, that there is integration of laboratory activities with the theory covered in class. The approach to physics is theory first and then verification of the laws of physics in the laboratory. Whilst this approach may be true, most of the practical offering in the Mechanics laboratory may be uncoordinated with what is done in class. It must be mentioned that the mean scores for the Integration scale is the highest for most of the laboratories and is indicative of the fact that laboratory practicals follows the theory covered in class in that order.

On the issue of Student Cohesiveness, the actual mean scores are generally higher than the preferred mean score and this is indicative of the fact that the students get along well with each other, helping and supporting each other in each of the laboratories. This is despite the fact that each student is allocated a separate cubicle workstation for him or her to do his or her laboratory work. Of particular note, the Mechanics laboratory having a limited number of cubicles compared to

the other laboratories, students in this laboratory are offered an opportunity to couple in pairs to do their laboratory work. This could be a possible reason for why the actual mean score (3.20) is higher than the preferred mean score (2.99). Whilst there is good collaboration and interaction between the students in each of the laboratories, their confinement to the cubicles in the overloaded Mechanics laboratory limits it from being a strong point.

The mean scores for Rule Clarity resonates fairly well with the mean scores for that obtained for Student Cohesiveness in each of the laboratories. In this scenario, the actual mean scores within this scale are higher than the preferred mean scores for each laboratory. This implies that the students have a fair understanding of the laboratory rules. Students are expected to conform to these rules at all times during their practical session. Having these rules well written and strategically placed in each laboratory does not mean that the students will abide by them. Sometimes students can break the rules as they are hidden from the teachers in their cubicle workstations. In general negative student behaviors are curtailed and order is maintained in the laboratories.

The difference in students' perception of the actual and mean scores for the Open-endedness scale is relatively small, except for the Mechanics laboratory where a sizeable difference exists. This means that the students are not in favour of a more open-ended laboratory session and prefer the way it is done at this university. This is further revealed from their lower preferred scores compared to their actual scores. This is of interest as in most universities; the practice maybe opposite to what is done at this university. They are in favor of the teacher telling them what is to be done instead of deciding what is to be done by themselves. They are happy with the existing protocol. However, as far as the Mechanics laboratory is concerned, more guidance by the teachers are required in how they should proceed as they have a fear of setting up mechanics practicals, despite it being recipe driven tasks. The students have favoured the Electricity and Thermodynamics laboratories more than the Mechanics laboratory because the cubicle set-up in the Mechanics laboratory is more restrictive than the other laboratories and this restricts their movement in class.

Results and discussion of the Physical aspect of the Laboratory Learning Environment

The results of the PSLEI data are presented in the Table 4:

Table 4: The average mean scores of the various physical factors of the PSLEI questionnaire for each of the three laboratories

No	Scale	Kinetics lab	Thermodynamic lab	Electricity lab
		Mean value	Mean value	Mean value
1	Furniture & Equipment	3.73	3.93	4.04
2	Learning Space	3.21	3.77	3.96
3	Lighting	3.83	3.62	3.77
4	Indoor Air Quality	3.48	3.33	3.37
5	Safety	3.61	3.37	3.86
6	Technology	2.86	2.86	2.98

Physical aspects between the Physics laboratories

From the data in table 4, students have rated most scales at a high level of fitness, except for the Technology scale. The Technology aspect in all laboratories is rated at a moderate level of fitness. These low levels of fitness may be attributed to the lack of computers in each of the laboratories. This has hindered them from obtaining information from the internet about the practicals. The computers, as an ICT tool, can be regarded as a pedagogical tool in assisting both staff and students to access information from the internet as well as in plotting of graphs. In this regard, it can be said

that the information provided by ICT technologies will help teachers to design their learning environment so that “students can manage and construct their own interpretation of knowledge in their minds” (Che Ahmad, 2017). Thus the lack of such technologies would have a negative impact on the students’ perception of the laboratory.

The mean score for Interior Air Quality for each of the laboratories are relatively the same. This means that the students’ perception of the Air Quality in each of the laboratories is the same and of good quality. The marginally higher score in the Kinetics laboratory could be attributed to the presence of an air extractor for the linear air track experiments. Big windows in each of the laboratories accounts for a reasonably good quality of air in each of the laboratories.

A high level of satisfaction was shown by students for Furniture and Equipment scale in each of the three laboratories. The Furniture, consisting of worktables, are arranged in a horizontal fashion in all laboratories. All laboratories, except the Kinetics laboratory consists of 24 technologically enhanced cubicles for the conductance of some 350 undergraduate practicals. Such an arrangement allows for easy access by teachers and for freedom of movement between cubicles. This set-up of the laboratories has a positive impact on the students’ learning.

In respect to the safety aspect, results show that the mean score of this scale to be moderately high. This implies that the students feel safe and comfortable to work in the laboratories. A high mean score of 3.86 for the Electricity laboratory in comparison to the Thermodynamics laboratory (mean score of 3.37) is because the Electricity laboratory has an extra steel gate used for the protection of radioactive materials housed within the Electricity block. A relatively high value for the Kinetics laboratory (mean score of 3.61) is because of the compactness of the laboratory and is a room comprised of three-side cubicles instead of one-sided cubicles in all other laboratories.

The combination of natural and artificial lighting in all laboratories is found to be of good quality for the students to do their laboratory work. This stems from the horizontal placement of light bulbs above each of the cubicle stations. Further, each cubicle station is enhanced with its own lighting for better illumination during practical work.

The set-up mentioned above allows for a more conducive and encouraging environment for laboratory work, in terms of Learning Space. In this situation, the role played by the teacher is meaningful as they are able to optimize the various activities through engaged interactions with each of the students at their cubicle positions. Thus, it can be said that the Learning Space is a place where constructive and meaningful learning unfolds.

CONCLUSION

In this study, it is revealed that there was a slight difference between the actual and preferred mean scores for the various SLEI scales for most of the laboratories. Such differences are an indication that the students were satisfied with the psychosocial characteristics scales pertinent to the laboratories. The classroom environment in terms of Moss’s (1979) framework was relevant in three categories i.e. Relationship Dimension, Personal Dimension and System Maintenance and System Change. However, of the psychosocial scales of the SLEI questionnaire, Student Open-endedness and Rule Clarity were found to be consistently low in all laboratories. The nature of the laboratory set-up and the arrangement of the cubicles could be attributed to this.

In terms of the physical characteristics and architecture of the laboratories, a conducive environment was made available for the students to do their laboratory work and for the development of conceptual understanding. The environment promoted active forms of learning on most of the PSLEI scales. These scales were aligned to Moss’s third criteria of the framework model

i.e. System Maintenance and System Change. This criterion was found to be relevant in both the physical and psychosocial frames of reference.

It is important from time to time to do an assessment of both the physical and psychosocial aspects of the laboratory as the information gathered can be used to improve the quality and effectiveness of teaching and learning (Che Ahmad et al. 2010). The effect of this is that if the needs of both the teachers and students are met then active form of learning will prevail in the classroom.

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CONSIDERATIONS FOR TEACHER PROFESSIONAL DEVELOPMENT: A CASE STUDY ON A COMMUNITY OF PRACTICE (THE A-TEAM TEACHERS)

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ABSTRACT: Two prominent reasons why South African learners perform poorly in science is teachers' under-developed pedagogical content knowledge (PCK) and a decontextualized school curriculum. Despite numerous teacher professional development interventions (TPDI), poor learner performance still plague science education. This paper reflects on research data emerged from a TPDI on the affordances of indigenous knowledge (IK) in the science classroom. The paper draws on social constructivism as theoretical lens, and the authors show how Warford's zone of proximal teacher development (ZPTD) could guide TPDI's. Third-generation Cultural-Historical Activity Theory (CHAT) is utilised as research lens, to identify problems often associated with TPDI's. From this mixed-methods study three themes are distilled, which suggest why many TPDI's are not effective. Firstly, the preliminary data indicate that many teachers lack nuanced understandings of the nature of respectively IK and science, to engage in effective epistemological border-crossing in the science classroom. Science teachers often lack understanding of the syntactical nature of the subject, and this has a negative impact on their pedagogies. The second distilled theme, is that facilitators of such interventions (teacher educators) often structure TPDI's based on their own perceptions of teachers' needs, and not the *real* needs that teachers experience. Often teachers struggle with more than just curriculum topics (content), and need guidance on classroom discipline, classroom- and stress management, and centralising the affective domain in the science classroom. The third theme indicates that most teachers require assistance with CAPS content. Data shows that many teachers have underdeveloped knowledge of optics as a Natural Sciences grade 8 theme. A recommendation is that teacher professional development is scaffold within well-established communities of practice.

Keywords words: Pedagogical content knowledge (PCK); teachers' professional development (TPD); zone of proximal teacher development (ZPTD); community of practice (CoP); views on the nature of science (VNOS); views on the nature of indigenous knowledge (VNOIK).

INTRODUCTION AND PROBLEM STATEMENT: CAN THE PHOENIX RISE FROM THE ASHES?

Much has been written on the dismal performance of South African science learners in international benchmark tests such as the Trends in International Mathematics and Science Study (Kriek & Grayson, 2009; Reddy et al. 2015) and the Southern and East African Consortium for Monitoring Educational Quality (SACMEQ) (Spaull, 2013). Many reasons are provided for this poor performance, but most researchers are in agreement that the quality of teachers is paramount to the situation. Spaull (2013) indicates that many South African teachers have below-basic levels of content knowledge (CK), with high proportions of teachers being unable to answer questions aimed at their learners. This is echoed by the Centre for Development and Enterprise (2011). Several researchers reflect on teachers' insufficient PCK (De Beer, 2016; Kriek & Grayson, 2009; Kunter, Frezel, Naggy, 2011; Lyons & Quinn, 2010; Mothwa, 2011). In the McKinsey study (Barber and Mourshad, 2007) it is clearly stated that no schooling system can rise above the limits imposed by the quality of its teachers. The key to improving science education, lies with teacher professional development. Another problem leading to underperformance in STEM education, according to literature, is the curriculum. Some scholars are of the opinion that the school curriculum is not contextualised well

enough for a diverse learner population, which could lead to under-performance (De Beer and Mentz, 2017; De Beer, 2016). This is probably one of the reasons for the current instability characterising South African education. A new form of protest swept South Africa as from 2015, in which dissatisfaction with the curriculum was expressed (Le Grange, 2016). Movements such as *#RhodesMustFall*, received massive attention when South African students demanded for the "decolonisation" and "transformation" of higher education institutions in South Africa, which resulted in huge damage to infrastructure, and disruption of education. Le Grange (2016) is of the opinion that the real motivation for the unrest was the need to decolonise the curriculum. The Department of Education has, to this effect, acknowledged that indigenous knowledge (IK) should be incorporated in the science curriculum. We concur with authors such as Abah, Mashebe and Denuga (2015, p. 672) who state that "while western science offers broader appreciation of context beyond the local level, IK offers depth of experience in a local, culture-specific context". Such infusion of IK in the science curriculum could address some of the perennial problems experienced in the school classroom.

A reason for the poor performance in science that is often overlooked is the affective domain of human thinking in science education (De Beer, 2016). From an embodied, situated and distributed cognition (ESDC) perspective, learning cannot take place in isolation (Hardey-Vallee & Payette, 2008). According to Maxwell and Chahine (2013, p. 67) effective learning takes place in a context of a learner's "existing knowledge, background and environment" and IK offers that context. These authors argue that IK holds affordances to make the science curriculum more relevant and accessible. Dubinsky, Roehrig and Varma (2013) shows us that experiences with an emotional stamp are more likely to become committed to long-term memory. Thus linking IK strongly with Natural Sciences themes might improve South African science performance. This would result in what Gibbons (2000) calls mode 2 knowledge construction, namely context-sensitive science. This paper emerges from a larger NRF-funded research project aimed to assist teachers in their professional development to better contextualise the science curriculum, and facilitate such epistemological border crossing, infusing IK into CAPS content themes.

The current lack of integration of IK in the CAPS could prevent us from solving certain local and societal problems such as improving water provision, poverty and hunger. Science subjects should develop skills that enable one to solve local and global challenges. This cannot be achieved if educators are not trained to teach this field of knowledge.

Cronje (2015) has shown that there is (despite several differences) many shared tenets when the nature of science and the nature of IK are compared. Both science and IK are empirical (although IK also has a metaphysical component), both are tentative (and subjected to change), both are inferential, both are creative, and both are socially and cultural based. The space where IK and Western ways of knowing connect and overlap can be understood as the 'cultural interface' (Nakata, 2002). This can be a contested space, but can also be a space where different ways of knowing work together synergistically. By infusing relevant IK into the curriculum themes, we might make science more interesting, more relevant for learners, and might sway the STEAM agenda forward (De Beer, 2016).

De Beer (2016) asks the question whether the phoenix (science education) can rise from the ashes. The answer, to a great extent, lies in teacher education. This is the focus of this paper. The authors advocate for a continuous TPD programme that aims to scaffold teachers' professional development and competence, among others the ability to better contextualize science through the infusion of IK. The paper focuses on lessons learnt during teacher professional development interventions.

THEORETICAL AND CONCEPTUAL FRAMEWORK

This study draws on social constructivism as a theoretical framework. We used Warford’s (2011) parlance on the well-known Vygotsky construct of the zone of proximal development (ZPD), namely the zone of proximal teacher development (ZPTD) as outlined in Table 1 below. We focused on the professional development of the science teachers involved in this study across this ‘zone of proximal teacher development’. The conceptual framework (or, in Engeström’s language, “intermediate theories”) included teachers’ PCK, indigenous knowledge, communities of practices (CoP’s) and problem-based learning.

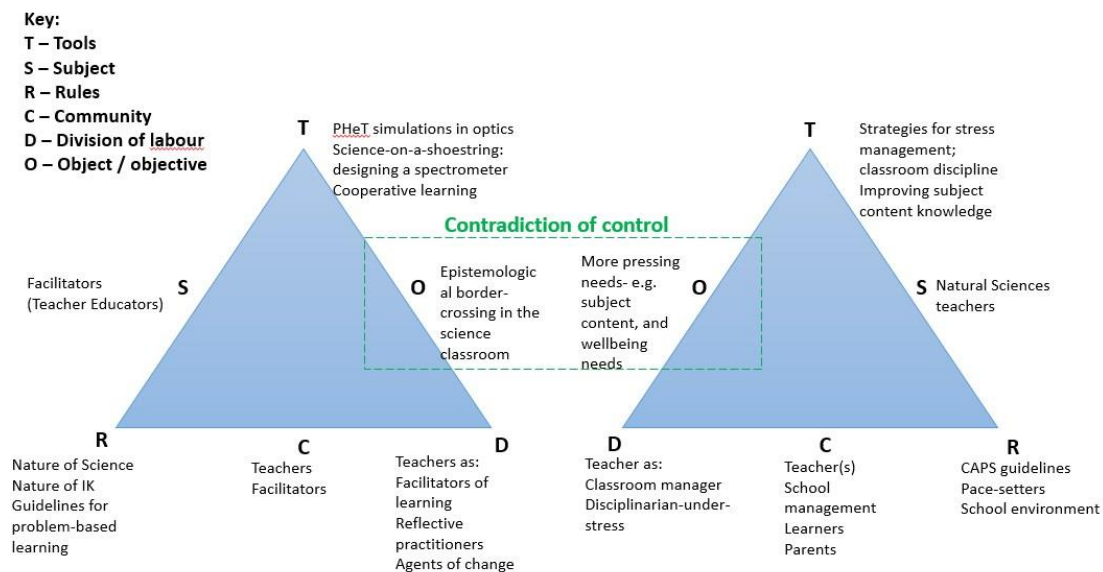
Table 1: Warford’s (2011) parlance on the well-known Vygotsky construct of the zone of proximal teacher development (ZPTD)

ZPTD (Warford, 2011)	Samples of Interventions	Activities in this SLP:
Self- assistance	Prior knowledge + experiences of teachers teaching optics/ Finding out what the teachers’ REAL needs are	World Café: Highlight experiences of teachers in teaching optics in the past; teacher reflections and discussions
Expert other assistance [Gallimore & Tharp, 1990]	Analysis of teaching practices- observing lessons (RTOP, videos, field observation) Scaffolding and mentoring by peers and facilitators	Leading questions and follow-up discussions Optic experiments PHET-simulations Jigsaw method (cooperative learning) Shoestring experiments designing a spectrometer Activities in managing personal wellbeing
Internalization (automatization)	Journaling Reflections Micro-teaching	Developing an evidence-based portfolio, with reflections Individual interviews Discussion
Recursion (De-automatization)	Journaling E-fundi (online forum) Role playing (<i>Homo ludens</i>) Reflection on ‘theory into practice’	Focus group interviews Classroom observation Discussion

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The paper report only on stages 1 and 2 of the ZPTD (Warford, 2011) namely the self- assistance and the expert-other assistance. The third generation Cultural-Historical Activity Theory (CHAT) as conceptualized by Engeström (1987) is used as research lens. The Cultural-Historical Activity Theory (CHAT) is fit to be used in this context, due to the complexity of South African science education which is influenced by cultural diversity, constant change and transformation in education, and history (i.e. Bantu education). CHAT is thus a nuanced lens to provide a meta-theoretical framework for understanding and analysing science education research and practices (Mentz & de Beer, 2017). The CHAT lens makes provision for a specific ‘gaze’ into the activity system- looking for an acting subject, an object of activity, tools and signs used in mediating the activity, rules for the system, the community in the system, and the division of labour in the system (see Figure 1). The authors used CHAT on an interpersonal plane, where two systems are compared. Mentz and de Beer (2017) used CHAT on the interpersonal plane and used two interdependent activity systems, in order to illustrate the so-called ‘contradiction of control’ (McNeil, 2013). CHAT offers a cross-disciplinary perspective for analysing human practices as development process (Mentz & de Beer, 2017).

In the first activity system (Figure 1) the subject is the facilitators of the short learning programme, and the object is facilitating professional development in terms of contextualised education. The second interdependent activity system (right triangle in Figure 1) is the experiences of the Natural Sciences teachers participating in the intervention (SLP). The subject is the Natural Sciences teacher, and the object is the teachers’ particular needs that should be addressed during the intervention.



Source: de Beer, J. J., & Mentz, E. (2017). A cultural-historical activity theory focus on the holders of indigenous knowledge as self-directed learners: Lessons for education in South African schools. *Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie*, 36(1), 11.

Figure 1: The contradiction of control in this study

In Figure 1, the activity system on the left focuses on the teacher educators who facilitated the learning activities during the short learning programme. The activity system on the right focuses on the experiences and needs of the Natural Sciences teachers].

RESEARCH METHODS, INSTRUMENTS AND DATA ANALYSIS

The research reported on in this article revolved around the following three research questions:

- What are the shortcomings of TPD programmes?
- What are the needs that the science teachers in this intervention (the *A-Team*) displayed, and how can this best be addressed in TPD?
- What are science teachers' experiences of infusing indigenous knowledge into science CAPS themes?

This paper focuses on ten (10) Natural Sciences teachers, residing in Ikageng and Promosa near Potchefstroom, who participate in a professional development programme. In this mixed-methods study, both quantitative and qualitative data were gathered, and the following instruments were used:

Views-of-the-nature-of-science (VNOS) questionnaire

The authors used the views-of-the-nature-of-science (VNOS) questionnaire developed by Abd-Elkhalick, Bell and Lederman (1998). This questionnaire focuses on teachers' views of the tenets of science, e.g. that science is empirically based, that there is a difference between scientific theories and laws, that scientific knowledge is creative and theory-laden, etc. The Views of Nature of Science (VNOS) instrument consists of ten open-ended questions based on the tenets of the NOS framework (Abd-El-Khalick *et al.*, 1998).

Views-of-the-nature-of-indigenous-knowledge (VNOIK) instrument

The authors used Cronje *et al.* (2015) views-of-the-nature-of-indigenous-knowledge (VNOIK) instrument. This instrument was developed based on the structure of the VNOS instrument, to capture teachers' views of the nature of indigenous knowledge. For both VNOS and VNOIK pre- and postquestionnaires were completed by the teachers.

Questionnaire: the A-team teachers' professional development needs

The authors developed a questionnaire to determine what the teachers' professional needs were. (d) Pre- and Post-test on optics construct (Using the jigsaw method)

Since the intervention focused on optics, the grade 8 Natural Sciences educators were requested to complete a pre- and post-intervention-test on the CAPS theme 'optics', to determine how knowledgeable teachers are on this curriculum theme. Out of the ten teachers involved in this study, only seven teachers completed both the pre-and post-tests.

The coding method of Saldaña (2009) was used, that led to the distillation of three emerging themes. The VNOS and VNOIK questionnaires were analysed according to the technique described by Cronje *et al.* (2015), in which teachers' responses were analysed as uninformed views, partially informed views, or informed views.

FINDINGS

Many teachers have uninformed or partially informed views on both the nature of science, and of indigenous knowledge, and this might negatively impact on contextualising science topics through border-crossing

The data collected showed that most of the teachers had either uninformed or partially informed views of the nature of science, and of indigenous knowledge. The data make it evident that teachers often have a naïve understanding of the tenets of science and IK, and need professional development to facilitate such epistemological border crossing in the science classroom. Teachers expressed the need for more support in addressing indigenous knowledge in curriculum themes, especially in relation to using more inquiry approaches. Teachers have also commented on how

systemic factors (e.g. “pace setters”) negatively impact on such initiatives (infusing IK in the curriculum).

TPDI’s should focus on real, and not perceived, needs of teachers

Most of the teacher responses showed that they do not only need assistance with curriculum themes, but also have personal development needs. One such need (expressed by three of the ten teachers) is to better manage stress- refer to Table 2.

Table 2: The A-team teacher’s classroom and their professional development needs

Teachers’ needs in terms of the learners they are teaching	n	Content (CAPS) themes in which teachers need more assistance	n	Teacher professional development needs	n	Personal wellbeing needs of teachers	n
Study techniques	1	Skeletal system	1	Different teaching methods	1	Stress management	3
Learner motivation	2	Evolution	2	Inquiry learning + practical work	2	Administration & management skills	3
Disruptive behaviour & discipline	4	Tissues	1	Addressing the affective domain (learner interest)	3		
Managing conflict in class	1	Intermolecular force	1	Teaching in overcrowded classrooms	2		
		Electricity	1	Classroom management	2		
		Chemistry	1	Dealing with learners using drugs	1		

It is clear from Table 2 that the teachers’ needs are not only centred around their knowledge of content and CAPS themes, but they also expressed the need to be equipped in methods to better assist learners in their education, and educators’ needs in well-being, e.g. stress management and administrative and management skills.

Teachers have under-developed knowledge about optics (lack of content knowledge) In the pre-test only one educator managed to obtain more than 50%, and the rest of the teachers obtained marks that were below a 50% pass rate. On average the educators scored 31.42% in the pretest. In the post-test the educators improved on average by 24.10%, and scored 55, 51% on average. (The post-test was written after participation in a cooperative learning [jigsaw method] activity). This is quite alarming, given the fact that the test covered Grade 8 optics concepts.

Table 3: Teachers performance on Grade 8 optics constructs pre and post test

Teacher participation	Mark Pre-test (35)	Mark Post-test (35)	Percentage increase
Teacher 1	12	15	9%
Teacher 2	12	14	6%
Teacher 3	9	18	25%
Teacher 4	9	22	37%
Teacher 5	15	26	31%
Teacher 6	18	22	12%
Teacher 7	2	19	48%
% Average	31.42	55.51	24.10

The question should be asked whether professional development programmes therefore adequately prepare teachers for teaching the themes in the curriculum in an inquiry –learning fashion. We have realised that a longitudinal and systemic approach is needed in this professional development programme.

CONCLUSION AND RECOMMENDATIONS

The CHAT lens (see Figure 1) clearly shows a ‘contradiction of control’, that stems from the teacher educators (the authors of this paper) and the Natural Sciences teachers striving for different objects in the activity system. This could negatively impact on the success of such interventions. This paper provides insight into a triad of considerations for teacher professional development (TPD), namely (1) that such programme developers should centre-stage teachers’ *real* professional development needs, and not just *perceived* needs; (2) address topical issues dominating education, e.g. the discourse on decolonizing the curriculum (through epistemological border-crossing between indigenous knowledge (IK) and the Curriculum- and Assessment Policy Statement (CAPS) themes, and (3) address teachers’ lack of PCK and subject knowledge.

The CDE report (2011) makes it clear that teacher professional development is best achieved within well-functioning and supportive communities of practice. Our recommendation is that TPDI’s should be contextualized in terms of communities of practice, over a longer period. Warford’s (2011) stages of scaffolding learning across the ZPTD could be a suitable theoretical framework underpinning teacher learning and professional development. Systemic issues, e.g. the lack of resources in many classrooms, should also be addressed during TPD. This “science-on-a-shoestring” approach has already been introduced to the *A-team* teachers. In the photograph below, the teachers are making spectrometers and engaging in spectroscopy, using everyday recyclable materials.



Figure 2: Teachers engaging in spectroscopy (Pictures published with their written consent).

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PEDAGOGICAL ORIENTATIONS OF NAMIBIAN PHYSICAL SCIENCE TEACHERS IN ENACTING CHEMISTRY DEMONSTRATIONS

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ABSTRACT: The use of practical work has become a common practice almost in every science classroom globally. Despite calls from the Namibian National Curriculum for Basic Education (NCBE) for practical work, teachers in Oshikoto region resort to enacting practical demonstrations due to certain contextual factors. In this study, we investigated Namibian Physical Science teachers' pedagogical orientations in orchestrating grade 8 chemistry demonstrations. Quantitative data were collected by means of a questionnaire survey administered to 87 grade 8 Physical Science teachers from Oshikoto region. Finding from this study revealed that majority of the teachers exhibited a preference for teacher-led demonstrations rather than entrusting practical activities to learners. Teachers indicated that during teacher-led demonstrations, learners acquire an understanding of science concepts, develop practical skills, and develop an interest in science. They considered the following factors as important in informing their decision to do teacher-led demonstrations during chemistry practical lessons: lack of equipment and resources, large classes and timetabled-time for practical lessons. Findings further showed that through teacher-led demonstrations, teachers frequently apply certain pedagogical actions. These include inviting learners to make a prediction, asking learner to explain their observations, and facilitating class discussions after demonstrations. This suggest that although demonstrations are teacher-led, teachers engage with learners to ensure that they are cognitively engaged.

Keywords: Practical work; practical demonstrations; pedagogical orientations; chemistry; physical science; contextual factors.

INTRODUCTION

In almost all countries, science education involves learners and teachers doing practical work. These practical works vary in form and intention. Millar, Le Marechal and Tiberghien (1999) believe that if researchers are to explore the effectiveness of practical work in achieving educational goals. Then, there are needs to provide clarity about the different types of practical work, their different purposes, and pedagogical approaches for each type. Despite calls for learners to do independent scientific inquiry where they have autonomy in formulating their own investigation and planning an inquiry, factors such as lack of resources, large classes, and the lack of class time have resulted in teacher practical demonstrations being the prevalent form of practical work in sub-Saharan countries (Ramnarain, Nampota & Schuster, 2016).

This study investigated the pedagogical orientations of Physical Science teachers when orchestrating chemistry practical demonstrations at schools in Oshikoto region of Namibia. The first author is a Physical Science teacher in this region and has particular interests in understanding how other teachers enact chemistry demonstrations in their teaching. Most schools in Oshikoto region, especially in Omuthiya, where the researcher teaches, are under-resourced in terms of science facilities, such as laboratories. The Education Management Information Systems (EMIS, 2015) report shows that out of 94 schools where Physical Science is offered as a subject, only 46 are equipped with science laboratories. The benefit of teachers using demonstrations in such a context has been recognized. Treagust (2007) points out that demonstrations can increase learners' cognitive involvement. He refers to the Predict-Observe-Explain (POE) approach by Gunstone (1995) that describes activities where learners are first asked to predict what would happen in a demonstration.

Thereafter, they observe the demonstration, and finally explain what they observed. The value of demonstrations is also advocated by the Namibian Ministry of Education and, it is prescribed in the Physical Science curriculum that most practical activities should be achieved through teacher-led demonstrations (Ministry of Education, 2010, 2015).

TEACHER PEDAGOGICAL ORIENTATIONS IN PRACTICAL WORK

The literature abounds with multiple definitions of what practical work entails. However, there is some consensus that practical work involves a hands-on activity. This is reflected in the definition by Lunetta, Hofstein, and Clough (2007) where they describe it as “learning experiences in which students interact with materials or with secondary sources of data to observe and understand the natural world” (p. 2). Consequently, Woodley (2009) also defined practical work in science as “a hands-on learning experience which prompts thinking about the world in which we live” (p. 49). According to Roth et al. (2006), practical work may be broadly classified into whole-class practical activities and independent practical activities. Whole-class practical activities involve mainly teacher-orchestrated demonstrations of phenomena and objects, whereas independent practical activities involve activities “carried out by the students themselves, usually working in small groups” (Millar et al., 1999, p. 33). Whole-class teacher-orchestrated demonstrations range from simple displays of objects such as the model of the heart to display objects related phenomena or showing how substances react with oxygen. The focus of this study was on the enactment of teacher-orchestrated demonstrations, and the pedagogical orientations that teachers display during these demonstrations.

Anderson and Smith (1987) used the term ‘orientations’ to describe teachers’ “general patterns of thought and behavior related to science teaching and learning” (p. 99). In accord with this definition, Hewson and Hewson (1987) refer to pedagogical orientations as a “set of ideas, understandings, and interpretations of experience concerning the teacher and teaching, the nature of content of science and students and the learning which the teacher uses in making decisions about teaching, both in planning and execution” (p. 194). Further to this, pedagogical orientation has been theorised as a component of pedagogical content knowledge (PCK) (Friedrichsen, van Driel, & Abell, 2011; Kind, 2016; Magnusson, Krajcik & Borko, 1999). The Magnusson et al. (1999) model emphasizes the role of pedagogical orientations in PCK. Herein, pedagogical orientations are defined as science teaching orientations and described as “teachers’ knowledge and beliefs about the purposes and goals of teaching science at a particular grade level” (p. 97). Pedagogical orientations manifest in pedagogical actions and these can include types of questions asked, the use of prompts, and facilitating collaboration and reflection (Gervasoni, Hunter, Bicknell, & Sexton, 2012). In accordance with this conceptualization of pedagogical orientation, this research investigated the pedagogical orientations of Namibian Physical Science teachers in enacting teacher-orchestrated chemistry demonstrations.

RESEARCH QUESTIONS

The research was guided by the following questions:

1. Do Namibian Physical Science teachers have a preference for teacher-led demonstrations or learner practical activities?
2. How do Namibian Physical Science teachers consider the importance of various learning outcomes when orchestrating demonstrations?
3. To what extent do Namibian Physical Science teachers consider the impact of various contextual factors when choosing whether to do a teacher-orchestrated demonstration or a learner practical activity?
4. What pedagogical actions are evident during teacher-orchestrated demonstrations?

RESEARCH DESIGN AND METHODOLOGY

A quantitative survey research design was adopted for this study. According to McMillan and Schumacher (2010), a survey may be used in an educational research to “describe attitudes, beliefs, opinions and other types of information” (p. 22) where data obtained from a smaller population may be generalized to a population from which such data emerged. The questionnaire used to gather data consisted of closed-ended items. This questionnaire is adapted from an online survey in the United Kingdom administered by Durham University called ‘Practical Work in Science-Science Teachers survey.’ The questionnaire is structured into sections that comprise items relating to learning outcomes of chemistry demonstrations, the impact of contextual factors on the types of demonstrations, and teachers’ pedagogical actions during demonstrations. The questionnaire was validated for the above constructs by three science education researchers. The adapted questionnaire was piloted with 3 Namibian grade 8 Physical Science teachers to establish the readability of items before it was adopted for this study.

The questionnaires were administered to 87 Physical Science teachers from the schools in Oshikoto region, Namibia. The great majority of schools in this region either have no resources or are poorly resourced for doing practical work. The average class size is 35. The majority of teachers have either a teaching diploma or an education degree. The participants were purposefully selected from grade 8 Physical Science teachers in Oshikoto region through a purposive sampling method. Merriam (2009) maintains that purposive sampling method is based on the assumption which the investigator wants to discover, understand, and gain insight and therefore, the sample must be selected from the area in which the most can be learned. The questionnaire data were analysed descriptively using SPSS software and involved the calculation of means, percentages and frequencies.

RESEARCH FINDINGS

In addressing the research questions, the findings are structured in terms of teachers’ preference for doing either a teacher-led demonstration or learner practical activities, envisaged learning outcomes for teacher-led demonstrations, the influence of contextual factors on the decision to do either a teacher-led demonstrations or learner practical activities and the pedagogical actions of teachers when doing teacher-led demonstrations.

Teachers Preference for doing either Teacher-led Demonstration or Learner Practical Activity

Teachers were asked to indicate their preference for either doing a teacher-led demonstration or learners to do a practical activity. Responses to the questionnaire showed that 57.3% of teachers expressed the preference to do teacher-led demonstrations.

Learning Outcomes for Teacher-led Demonstrations

In the questionnaire, teachers were asked to respond to a list of envisaged learning outcomes by rating these as “unimportant”, “of little importance”, “moderately important”, “important” or “highly important”. Teachers considered the following learning outcomes as either “important” or “highly important” during teacher-led demonstrations: helping learners to understand science concepts (97.7% teachers); developing learners’ science skills such as handling apparatus (93.1% teachers); stimulating learner interest in science (95.4% teachers); help learners observe physical changes in science phenomena (95.4% teachers); and developing social skills in learners (96.6% teachers).

Impact of Contextual Factors in Choosing to do a Teacher-led Demonstration

The respondents were asked to rate the degree of the impact of certain contextual factors on a scale of 1 to 5, where 1 indicated “no impact” and 5 indicated a “high impact”. The analysis of data revealed that teachers considered the availability of equipment and resources, the amount of lesson timetabled time for practical activities, and the number of learners per class (class size) as key

factors in their decision to do teacher-led demonstrations rather than having learners do practical activities. This finding is presented in the following table.

Table 1: Rating of contextual factors in decision to do teacher-led demonstrations

Contextual factors	Degree of Impact				
	No impact 1	2	3	4	High impact 5
Availability of equipment and resources N (%)	2(2.3%)	4(4.6%)	5(5.7%)	19(21.8%)	57(65.6%)
Lesson timetabled time N (%)	3(3.4%)	2(2.3%)	16(18.4%)	24(27.6%)	42(48.6%)
Class size N (%)	0(0%)	11(12.6%)	7(8.1%)	31(35.6%)	38(43.7%)

Note. N = number of teachers who made this choice.

From this table, it is evident that 76 teachers (87.4%) rated either 4 or 5 the impact of the availability of resources in their decision to do teacher-led demonstrations. A similar result was noted for the impact of class size where 79.3% of teachers rated the importance of this factor as either 4 or 5. For lesson timetabled time, 75.9% of surveyed teachers rated the impact level of this factors as either 4 or 5.

Pedagogical Actions during Teacher-led Demonstrations

In this section of the questionnaire, teachers were asked to indicate an option on the frequency within which they displayed certain pedagogical actions when doing teacher-led demonstrations. Teachers were required to elect one of the following options for each listed pedagogical action: no demonstrations; a few demonstrations; about half the demonstrations; most demonstrations or all demonstrations. The data analysis revealed that teachers who opted for either “most demonstrations” or “all demonstrations” displayed the following pedagogical actions: ask learners to predict the results (89.7%); ask learners to explain their observations (95.4%); and facilitate a class discussion after the demonstration (89.7%). To a lesser extent, 52.8% of teachers “Wrote the results on the board for learners to copy in their books” either for “most demonstration” or “all demonstrations”.

DISCUSSIONS, IMPLICATIONS AND RECOMMENDATIONS

This study focused on the pedagogical orientations of Namibian grade 8 Physical Science teachers when enacting chemistry practical demonstrations. The findings of this study showed that teachers enact demonstrations during the allocated timetabled time for practical work. This finding is in accordance with the prescript advocated by the Namibian Ministry of Education that most practical activities should be achieved through teacher-led demonstrations (Ministry of Education, 2010, 2015). Given the influence of contextual factors that teachers in Namibia experience such as lack of equipment and resources, lack of timetabled time, and large class sizes, it would appear from the results of this questionnaire survey that teacher-led demonstrations are regarded as being the most effective forms of practical work by which learners can derive learning benefits such as acquiring an understanding of science concepts, developing practical skills, and developing an interest in science.

From the findings it can also be gleaned that although the demonstrations are teacher-led, the pedagogical actions of the teacher suggest that the learners are cognitively engaged. At the start of the demonstration, teachers invite learners to make predictions based on their prior knowledge or experience. During the demonstration learners are prompted to explain their observations. After the demonstration, learners are engaged in class discussions. From this, an inference can be made that the chemistry demonstrations enacted by teachers in the Oshikoto region of Namibia take on a form of a whole-class activity and resemble the POE approach by Gunstone (1995) that describe activities

where learners are first asked to predict what would happen in a demonstration. Thereafter, they observe the demonstration, and finally explain what they observed. The findings of this questionnaire survey invite further investigation into the classroom practice during demonstrations, with a view to collecting rich qualitative data on communication structures emanating from teacher-learner and learner interactions.

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A CASE STUDY OF THE PEDAGOGICAL ORIENTATIONS OF PRE-SERVICE PHYSICAL SCIENCES TEACHERS IN ONE OF THE SOUTH AFRICAN UNIVERSITIES

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ABSTRACT: The most critical aspect of teacher education is attaining ways of teaching science for learner's conceptual understanding, however, in most methodology modules students are not widely exposed to varied ways of teaching science topics. To teach science successfully, teachers need both appropriate content knowledge and pedagogical knowledge to translate knowledge into appropriate teaching approaches for specific topics. The study investigates physical science pre-service teacher's pedagogical orientations in one of the South African universities. 'Orientation' is teacher's knowledge and beliefs for teaching science. Based on research done in South Africa, orientations are classified into two approaches; direct approaches and inquiry approaches. The pedagogy preferences were measured using an instrument/questionnaire comprising of ten items that portrayed an actual teaching scenario for physical sciences topic. Each item had four alternative teaching methods, students were expected to select the most appropriate and the most inappropriate choice and a space for justification was provided. A quantitative approach was adopted to obtain the pre-service teacher's pedagogical orientations and their justifications. The results showed that students preferred an inquiry approach, aligned with the guided inquiry, while a smaller group of students preferred the direct didactic as the most appropriate teaching approach.

Keywords: Pedagogical orientations; pedagogical content knowledge; pre-service teachers

INTRODUCTION

Universities in South Africa attract most of their student teachers' cohort from previously disadvantaged schools in the townships and rural areas. These pre-service teachers have a limited science knowledge due to distinct reasons such as the limited availability of science teachers, large numbers of under-qualified or non-qualified physical science teachers and overcrowded classes (Makgatho & Mji, 2006). Furthermore, learner's lack of science knowledge stems from the understanding that some teachers from these schools have science inadequate content knowledge (Nezvalová, 2011).

When these pre-service teachers start their methodology modules at university, they bring images about teaching they have construed from their previous teachers (Cross & Ndoferipi, 2013) that do not comprise the inquiry or learner centered teaching approaches but teaching strategies that are mostly teacher centered. At university, pre-service teachers are expected to transform their teaching styles to accommodate inquiry-based learning and other teaching approaches that benefit learners. They are expected to have an adequate knowledge and strategies to teach science in different ways through the process of inquiry (Beni, Stears & James, 2012).

A key dimension being investigated in science education is teacher's pedagogical orientations. The term 'orientation' insinuate teacher's knowledge and beliefs about the purposes and goals of teaching science at a particular grade level (Magnusson, Krajcik, & Borko, 1999). The aim of this study was to explore the pedagogical orientations of pre-service physical science teachers' in one of the universities in South Africa.

To achieve the aim of this study, the following research question was set:

- i. What are the pedagogical orientations of the year 2018 Bachelor of Education 4th year physical science specialisation pre-service teachers in one of the South African university?

The study identified teacher's pedagogical orientations using an existing pedagogical orientation instrument in the form of standard MCQ format developed by Cobern, Schuster, Adams, Skjold, Muğaloğlu, Bentz, and Sparks (2014).

THEORETICAL FRAMEWORK

The Pedagogical Content Knowledge (PCK) underpinned this study as a theoretical framework. PCK is a blend of pedagogical and content knowledge that formulates the transformation of these two knowledge into the most powerful, teachable forms to formulate subject and make it comprehensible (Shulman, 1987). Within PCK, Magnusson, Krajcik, and Borko (1999) identified teacher's orientations. These are "teachers' knowledge and beliefs about the purposes and goals of teaching science at a particular grade level" (p.97). These orientations play a pivotal role in shaping teachers decisions and goals for science in the science classroom.

The research on measuring pedagogical orientations of teachers has been conducted around the world. A group of the University of Western Michigan developed a framework comprising a set of case-based assessment items that present realistic teaching scenarios for a science topic (Cobern, et al., 2014). These assessment items are multiple-choice questions but differ from conventional multiple-choice questions in that each of the response options represents a pedagogical orientation, rather than a normal MCQ. These items aim to elicit teachers' orientations towards teaching science and encourage the teacher to visualise himself or herself in a teaching situation, play the role of a decision-maker, and respond as if he/she is going to teach that lesson.

Literature shows various classifications of pedagogical orientations. Based on research done in South Africa by Ramnarain and Schuster (2014), they classified orientations into two approaches which are; direct approaches divided into direct didactic and direct interactive modes and the second approach is an inquiry approach divided into guided inquiry and open discovery. Below is the classification of pedagogical orientation based on the research done in South Africa by Ramnarain and Schuster (2014).

- i. A **direct didactic approach**, a teacher presents and explains the science concept or principle directly to the students and illustrates with examples and/or demonstrations. Students apply this knowledge to questions and problems. There are no or few student practical activities in this method, but there are usually discussions and problems with the content.
- ii. A **direct interactive** orientation similarly entails direct teacher exposition, but this is followed by a student activity based on the presented science content, for example, hands-on practical verification of a law.
- iii. In adopting a **guided inquiry** orientation, the teacher plans an activity where students explore a phenomenon or idea, and from this, the teacher guides them to develop the desired science concept or principle.
- iv. In **open inquiry**, students explore a phenomenon or idea on their own, devising ways of doing so, minimally guided, after which they report what they did and found. The teacher facilitates the student activity but does not intervene more than necessary.

EXAMPLE ASSESSMENT ITEMS

To show the nature of the items, for this paper one example item is shown in full, although five items were analysed. All these items follow the same format, namely, vignette, pedagogy question, four options and a space for justification. However, they involve various aspects of science either


physics or chemistry. Some items focus on an investigation and other items focus on a new science concept.

Example item 1: Temperature and Solubility

This item involves alternative approaches for learning a basic solubility concept and to make a comparison between sugar and salt solubility.

Temperature and solubility

Ms. Clark's 7th graders have learned that sugar becomes more soluble in water as the water temperature increases. Now she wants her students to learn that, unlike sugar, the solubility of salt does *not* increase with temperature. Graduated cylinders of hot and cold water, salt, sugar, and stir sticks are available.



Thinking about how you would teach, of the following, which one is most similar to how you would conduct this lesson?

- A. I would explain that while we found that sugar is more soluble in hot water, not all solids behave the same way. I would demonstrate using salt instead of sugar in the graduated cylinders of hot and cold water.
- B. I would pose the question of whether all solids might dissolve better in hot water like sugar did. I would ask them to design and do an experiment to test whether salt dissolves better in hot or cold water.
- C. I would give my class sets of graduated cylinders, salt, sugar, and hot and cold water, and ask them if they could find out anything about salt versus sugar dissolving in water. I would not prescribe what they should do. Later, we would discuss what they did and what they found out.
- D. I would explain that while we found that sugar is more soluble in hot water, not all solids behave the same way. I would then have them verify this in the lab using the same amount of salt in each cylinder of hot and cold water.

Figure 1: Example item 1, Temperature and Solubility

Although this example and other items that are not presented in the paper involve various aspects of science, the shared aims the pedagogy response options are apparent. Assessment items such as these can be used either individually or compiled into instruments that comprised of either 10 or more items if the aim of the research is for quantitative research.

RESEARCH METHOD

This study adopted a quantitative design approach, we administered questionnaires to the participants then we used the results to best understand a research problem or question (Creswell 2003). Firstly, we studied only the first five items in the questionnaire, the student responses were used to build on the results of the initial quantitative results. The questionnaires were administered to all the year 2018 Physical Science specialisation Bachelor of Education 4th year students in one of the South African universities. The sample comprised of only forty-five (45) students and each questionnaire had ten items, only the first five items were studied for this paper.

In the final year of study, students take a year module on the methodology of physical sciences teaching. One of the core themes is to enable students to understand the nature and significance of physical sciences and then develop competencies necessary for successful and effective teaching in physical sciences and PCK features as a topic within this theme. Also, the final year students are expected to attend a fourteen week school teaching practicum that is divided into three sessions throughout the year. During this time students are expected to be junior members of the school's staff and comply with the school policies and those of the university. A senior teacher at a school where the students are assigned is expected to act as a mentor for the student. During this time students conduct lesson observations, they are required to teach several lessons and are encouraged to be reflective of their practice and justify pedagogical actions taken.

DATA ANALYSIS AND RESULTS

A quantitative data in the form of responses to the questionnaire items were analysed statistically to obtain distributions for teacher's preferred pedagogical orientations for only five items, using SPSS—PASW. Only percentages and frequency were analysed with which Data in the form of options were arbitrarily coded as follows: 1= didactic direct; 2 = direct interactive; 3 = guided inquiry and 4 = open inquiry. Thereafter, the coded data were analysed by employing descriptive statistics. In the questionnaire, space was provided for justification and these justifications were used for qualitative purposes. The results of the quantitative data collected through the questionnaire are presented below together with the qualitative findings that enabled us to better understand the quantitative results. Response data from all the five items are presented in table 1 below. Students were requested to select the most appropriate orientation and the most inappropriate orientation. Table 1 presents all the options, the appropriate and the most inappropriate options students selected in percentages.

Table 1: Results for the overall first five items that were analysed for student's preferred pedagogical orientations in percentages (%).

	The most appropriate					The most inappropriate				
	Temperature and solubility	Lesson on force and motion	Air is matter	Light and shadow	Light reflection	Temperature and solubility	Lesson on force and motion	Air is matter	Light and shadow	Light reflection
DD	9	20	16	0	18	33	49	40	49	36
DA	18	40	11	7	29	20	13	20	33	20
GI	47	18	38	29	44	11	9	7	11	18
OP	27	22	36	64	9	36	29	33	7	27
Total %	100	100	100	100	100	100	100	100	100	100

Table 1 shows the quantitative results of the most appropriate and the most inappropriate choices pre-service teachers selected. Under the most appropriate choice, Guided Inquiry was the most preferred pedagogy among the five items that we studied. While Direct Didactic was the most inappropriate approach from the data provided.

Response Data from the first example item: Temperature and Solubility.

Response data from the first example item: temperature and solubility is presented below on figure 3, temperature and solubility in the form of stack bar graph for the forty-five science pre-service teachers who participated.

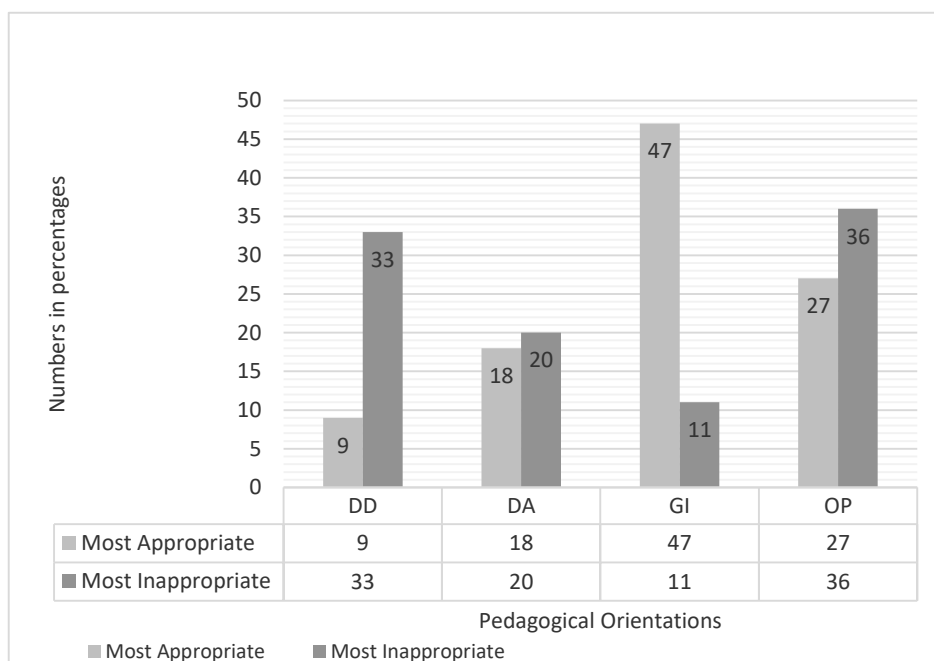


Figure 2: The proportionality distribution of response data from the first example item: Temperature and Solubility

The difference in distributions is evident. For this item, Guided Inquiry (47%) was the most common choice, but beyond this, Open Inquiry (27%) was the second choice, reflecting a clear difference overall. In contrast, a relatively small percentage of students selected Direct Didactic (9%) and Direct Active (17%) as the most appropriate. Overwhelmingly, the students regarded Open Inquiry (36%) as the most inappropriate orientation when teaching this topic.

The quantitative results indicate that from the analysed responses provided by only forty-five science pre-service teachers from one university in South Africa exhibited a preference for learner-centred teaching method which is more guided inquiry than other approaches, while a minor group of students preferred the teacher-centred approach, which is active direct and direct interactive orientation. In South Africa, inquiry-based learning is receiving an attention from curriculum developers and currently, the South African National curriculum put an emphasis on the inquiry-based and the university teacher education programs also are putting an emphasis in this approach. This could be the reason why most of the students preferred guided inquiry teaching approach since in their methodology modules is being emphasised.

Qualitative Results: pre-service teacher’s pedagogical orientations justifications

The Science pre-service teacher’s justifications were obtained from the space that was provided at the bottom of the vignettes. All participants were required to justify for both choices, the appropriate and inappropriate choices for understanding. It was evident from the data that factors such as curriculum expectations, learner’s needs, availability of resources, yielded a considerable influence on the pre-service teacher’s pedagogical preference. The justifications assisted us to generate assertions that explain the quantitative data. For this paper, only one assertion is provided. The assertion is presented below, along with their warrants in the evidence.

Assertion 1: learner’s needs, high order thinking, and skills for the future: The first assertion is a combination of different skills that learners are expected to obtain in science. Students who selected either guided inquiry or open discovery were thinking about learner’s needs, in other words, a lesson

need to develop necessary skills for future, develop critical skills and how to manipulate science laboratory equipment.

According to physical science specific aims, we equip learners with investigative skills such as measuring and drawing a conclusion as well as skills of using apparatus and practical work.

The other student selected open discovery because it provides an opportunity for learners to manipulate science laboratory equipment.

I would use option D that is open discovery. Learners need to be able to manipulate real objects and materials to come up with own ideas and understanding. This approach will allow learners to interact, discuss, and move about. As a teacher, I would mostly focus on the process, not the results.

Student's responses defined or explained open discovery and guided inquiry interchangeable, to them they are both learners centred and serve same or similar purposes.

DISCUSSION AND CONCLUSION

The findings from the first five items that were used in this study reflects that the 45 pre-service teachers from this university exhibited a preference for learner-centred teaching method which is more guided inquiry than other approaches. The findings of this study have revealed not too much significant differences in the pedagogical orientations as they have a strong guided inquiry orientation. The factors or determinants that resulted for pre-service teachers to select guided inquiry include the curriculum expectations, the goals of practical work and learners needs among the few that were listed by the participants.

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CONTEXTUALISING SCIENCE AND MATHEMATICS TEACHER PROFESSIONAL DEVELOPMENT IN RURAL AREAS

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ABSTRACT: Science and mathematics teacher professional development in South Africa has not improved teachers' pedagogical content knowledge, content knowledge or ability to integrate indigenous knowledge into the curriculum. This situation is partly due to traditional teacher development programmes that utilize top down and expert driven approaches without consulting teachers. This "one size fits all" model is rarely relevant to teachers' classroom realities, especially in rural areas. In this paper, we explore the design principles for teacher professional development interventions that could address the needs of both teachers and the context, acknowledging that teachers in rural areas face different challenges compared to teachers in urban areas. We use the Hantam region of the Northern Cape Province as a case study to explore the affordances of partnerships with local indigenous knowledge holders and cultural institutions (museums) in professional development of teachers. Data were generated from semi-structured interviews with Hantam school and community participants using a qualitative approach. Findings revealed that education in the rural Hantam area has social, cultural and economic implications. We argue that contextualizing science and mathematics teacher professional development for the rural environment has affordances for improving teacher competencies.

Keywords: Teacher professional development; contextualized curriculum; indigenous knowledge; rural areas; science and citizenship education

INTRODUCTION

In South Africa, education is essential for redressing past injustices and transforming society into a democratic nation-state. The Department of Education asserts that education is pivotal to economic prosperity and plays a key role in enabling citizens to improve the quality of their lives in contributing to a peaceful, productive, and democratic nation (Department of Education, 2005). Positioned on the front lines of educational reform were science, technology, engineering and mathematics curriculum construction of which professional development was a critical component (Villegas-Reimers, 2003). In order to be a global player in the world economy, South Africa needs innovative, creative scientists but this means that science education in the country should be greatly improved (Centre for Development and Enterprise, 2011). Traditional teacher professional development in the form of workshops, conferences, courses, and seminars were initiated to improve identified skill deficit areas in content, curriculum and pedagogy (Rogan, 2004; Taylor, 2008; Kriek & Grayson, 2009). However, after two decades, teacher competency has not improved (Tsoetsi & Mahlomaholo, 2015; de Beer, 2016). Researchers note that many professional development programmes are imported products, implemented uniformly from a top-down perspective and based on expert knowledge that was irrelevant to the classroom realities of teachers specifically in rural areas (Ball & Cohen, 1999; Bantwini, 2009; Ono & Ferreira, 2010; De Beer, 2016). In this paper, we reflect on design principles for teacher professional development interventions that could better address the needs of both teachers and the sector. We aim to address the gap between teacher professional development and educational needs by investigating how teachers could be assisted to infuse indigenous knowledge into the science and mathematics curricula. This research contributes to the national "decolonizing of the curriculum" debate by contextualizing teacher professional development for a rural environment. The research question guiding this research was: *How could the professional development intervention be contextualized to better meet the educational needs of a rural environment?*

Many rural schools are located on former homelands, previously disadvantaged areas with a multitude of challenges to quality education (McKinney, 2005; Stack *et al.*, 2011). Rural areas represent the poorest and least resourced areas of the country; however, science in these contexts is embedded in local indigenous knowledges of the environment through generations of observation and experiences (Aikenhead, 1996). De Beer and Mentz (2017) have shown that the holders of indigenous knowledge were often, per definition, self-directed learners who solved problems in their environment through processes very similar to the syntactical tools utilized by scientists. Through oral transmission, indigenous ways of knowing and practicing science, mathematics and technology are vibrant in rural environments (Khupe, 2014). Researchers have documented the influence of cultural background on science education (Cameron, 2010; Manzini, 2006) as well as the connection between science and citizenship (Irwin & Wynne, 1996; Jasanoff, 2004). This paper explores teacher professional development from a community-based approach, recognizing that schools are integrated into the fabric of rural communities. We explore the affordances of partnerships with indigenous knowledge holders and cultural institutions (museums) in the professional development of teachers. Like Jautse, Thambe and de Beer (2016), we allude to the fact that a ‘third partner’ is needed in the value chain between schools and universities (teacher training institutions), to effectively prepare science teachers for a complex 21st century.

We argue from the perspective of embodied, situated, distributed cognition (ESDC) that grants the body a central role in cognition (Wilson, 2002; Hardy-Vallee & Payette, 2008). Cognition is physiologically embodied, socio-culturally situated and distributed among the community. ESDC emphasizes the connection between brain/mind and ongoing interaction with the physical and social environment (Reichert & Rossmanith, 2008). This cognitive system guides action (Wilson, 2002). An important implication of ESDC is the role that different modalities such as bodily movements and cultural artifacts play in the understanding of science and mathematical concepts. This provides a sound basis for context specific professional development that is responsive to culture and relevant to teacher needs. However, we employ a contextualized approach to professional development that engages knowledge and cultural assets of the local community, acknowledging that schools in rural areas are not entities separated from the cultural community.

METHODOLOGY

This research was designed to investigate a professional development short learning programme for science, technology and mathematics (STEM) teachers in the Hantam area in the Northern Cape. The Hantam professional development course is an example of professional development that considers the social, cultural and historical context of rural education. According to Stake (2005), a case study is distinguishable by its unit of study in a bounded system. Yin (2014) adds that a case study is an empirical inquiry investigating a phenomenon in its real life context. This research proceeded as a qualitative case study because the boundaries between phenomenon and context were blurred (Yin, 2014).

The Hantam region is bounded geographically by the Hantam Mountains, with the town Calvinia forming the hub of the region. It contains flora, fauna, indigenous knowledge and culture that is specific to this geographical region. Of specific interest, is that a sizable proportion of the people in this area are of Khoi-San (Nama, Griqua and *!Xam*) ancestry (de Beer, 2012). Adhering to design-based research described by Anderson and Shattuck (2012), this research requires long term engagement and intensive collaboration in the research context to improve the short learning programme. The first cycle of the design-based research started with a short learning programme in the Hantam district. A total of seventy-seven (77) teachers attended the intervention, thirty seven (37) science teachers and forty (40) mathematics teachers. Teachers voluntarily completed one-on-one interviews during the two-day intervention. After the intervention, they were granted six

months to complete portfolios documenting application of professional development skills and indigenous knowledge integration into their classroom instruction. Data obtained from teacher interviews and professional development portfolios assisted facilitators to distil new design principles to better serve the educational needs of teacher in the rural Hantam context.

Cycle 2 of the design-based research began seven months later with a community-based qualitative inquiry exploring indigenous knowledge resources and the educational needs of the sector. The community inquiry and intervention follow up ran concurrently. A snowball sampling method was used to invite Hantam residents to participate in this cycle of research. Semi-structured interview conversations were conducted with eight community members (notably the holders of indigenous knowledge) museum staff and officials from the Department of Education. Ethical clearance was obtained from both the university and community gatekeepers. Two participants volunteered to record video narratives explaining indigenous knowledge and Hantam culture. Data included researcher observations/field notes, interviews, visual/cultural material and cycle 1 data. Interviews were transcribed and data was descriptively coded according to Saldaña's (2009) coding technique. Codes were grouped into categories and themes emerged from comparison of categories with the research question. This paper reports preliminary findings of the ongoing design-based research. This cycle of research provides a basic frame for professional development intervention research in similar cultural and indigenous contexts. Four themes emerged from the data, of which two are highlighted and discussed in this paper.

FINDINGS

Themes emerging from the data show that education in the Hantam rural environment is embedded in the social and cultural fabric of the area. Education is connected to indigenous knowledge, cultural artifacts and issues of social justice. Professional development initiatives would do well to consider the cultural context of rural schools to better meet the needs of teachers in these environments. This paper reports preliminary findings of ongoing research.

Theme 1: Social connectedness of education, and contextualized STEM education

Participants indicated that education in the rural environment is not an isolated institution. Memci, the Calvinia Museum Curator, stated that she often collaborates with teachers and students to provide resources and needed support for teachers.

Every year, foundation phase learners come to the museum to do their history project. I take them on a tour of the museum and show them the resources we have here. I work with the teachers to organize the learners to come every year.

Memci nurtured the educational connection between community and schools by providing cultural and historical artifacts to assist learners in constructing history projects. In the Hantam rural context, sustainable professional development should utilize already existing community connections.

Education in the Hantam is everyone's business. Gammie, the local traffic policeman utilizes the school to connect students with cultural knowledge through the Rieldans. The Rieldans is a Khoi-San cultural knowledge form that promotes cultural identity and community engagement (van Wyk, 2013). Gammie boasts:

The rieldans is the property of the Khoisan people. It is their knowledge and identity. The rieldans is important because people of Khoisan roots are losing their identity from Western influence.

Gammie's dance troops are students in local schools that come from farms. His work maintains the connection between farms and schools in the Hantam. Gammie explained how he uses the rieldans to encourage educational achievement:

I tell them they can do anything. They can use what they learn on the farm in school. The rieldans is knowledge of the farm and they can be proud of what they know from the farm.

The need for contextualized teacher professional development prompted the teacher educators in this project to focus on the affordances of traditional music for learning in the Mathematics classroom. Due to generous funding obtained from the Fuchs Foundation, teachers and school learners were provided with 'boomwhackers', plastic pipes of various lengths, that can be used as music instruments. These boomwhackers were accompanied by sheet music, in which learners are taught about fractions (see Figure 1).



Figure 1: Teaching fractions in the Mathematics classroom- inspired by indigenous music.

Additionally, Khoi-San indigenous knowledge and culture is embedded in the Hantam local culture. Education is not separate from social and economic issues affecting Hantam residents. Christien, an indigenous knowledge holder staying on a farm in the Agter-Hantam, stated:

I wish I could have been a teacher so I can teach the children about my plants and medicines. It is important for them to know what plants can do.

Christien's desire to pass on or transmit knowledge to future generations is a tenet of indigenous knowledge. She also recognized the importance of Khoi-San indigenous knowledge to science education in Hantam classrooms as she referenced medicinal properties of plants. Christien also recognized the connection between education and economic issues in the farm community.

My son has the knowledge. He wanted to be a teacher but we work on the farm. We don't have money to send him to varsity.

Christien's dream of transmitting indigenous knowledge to teachers and students can be realized through the local museum. The museum curator agreed to house a memorial garden of Khoi-San medicinal plants, indigenous to the Hantam. The museum will also house a permanent exhibit of Khoi-San indigenous knowledge and influence in the Hantam area. These exhibits are an outgrowth of the cultural research we embarked on to contextualize the professional learning intervention.

In the second half of 2017, we embarked on a teacher professional development programme for Life Sciences teachers, in which the insight about the importance of ethnobotany in this region resulted in tailor-made activities. De Beer and Van Wyk (2011) conceptualized the so-called Matrix Method for engaging in ethnobotanical surveys in the classroom. Teachers' learning was scaffolded in this regard, and they were introduced to ethnobotanical activities that learners can engage with in the Life Sciences classroom, such as an adapted Kirby-Bauer technique (Mitchell & Cater, 2000) to test whether medicinal plants that are culturally used, have any antimicrobial activity, as well as doing ethnobotanical surveys in the community. One of the teachers, Marlize, indicated that this resulted in much enthusiasm among her learners, and the attainment of affective outcomes. One of the teachers started a project where her learners engaged in making herbarium voucher specimens, for a class herbarium (See Figure 2).



Figure 2: Resources that were provided to schools (herbarium presses and autoclaves) on the left-hand side, and a learner's project in ethnobotany on the right-hand side.

Theme 2: The affordances of indigenous knowledge in STEM education, for building self esteem

Community participants indicated that they were alienated from educational institutions in the past. However, educational opportunities are available for adults since 1994. For Gertjie, education was connected to social justice. He was unfairly denied education in his youth because he lived on a farm.

I had to work on the farm. When I could go to school, the farmer said I had hair on my face, I need to work on the farm.

When educational opportunities were made available, Gertjie was denied the privilege of going to school because “he had hair on his face” (referring to the fact that, as an adolescent, he had a beard), otherwise stated he was too old and more useful as a farm worker than as a learner in school. In adulthood, Gertjie realized education as his human right through literacy programmes. He can now learn to read and write. In his words:

No one has to read for me, I can read myself.

Education is embedded in community life, but local indigenous knowledge is not common in school classrooms. Carin, a foundation phase administrator, asserted:

Khoi-San indigenous knowledge and stories should be in the curriculum to build confidence in the learners. Most of them (learners in her school) are Khoi-San. They have the knowledge at home and in their communities, but it has to stay at home when they come to school.

Integrating communities in schools holds innumerable benefits for building children’s self-esteem. Older participants stated that indigenous knowledge was confined to the realm of the home. It was not valid in schools. Carin explained that Khoi-San indigenous knowledge is the way that she knows in the veld. She grew up hearing Khoi-San stories about the veld. She learned about the environment and atmosphere from those stories. She regards indigenous knowledge as essential for building the self-esteem of children. However, this knowledge is not included in the curriculum.

The intimate connection between education, community and indigenous knowledge in the Hantam is best illustrated by a vignette from Marlize’s ethnobotanical survey. One of her Grade 10 learners, Henrico, was so inspired by this assignment that he visited the Calvinia library, and he asked the librarian for books on the flora of the Hantam. He was given a dissertation on the ethnobotany of the Hantam (de Beer, 2012), and while working through the text, he stumbled upon a photograph of his uncle, Martiens. The latter was consulted during this ethnobotanical survey in 2012. Henrico was so inspired by this “knowledge in the blood”, that he decided that he would like to pursue a career in botany after passing Grade 12. The acknowledgement of his own cultural knowledge did much to build his self-esteem, and a sense of pride in his rich Khoi-San heritage.

DISCUSSION

Nelson Mandela (2005) stated the “the most profound challenges to South Africa’s development and democracy can be found in its rural hinterlands” (pp. vi). Rural environments are typically areas of high concentrations of poverty, unemployment and low educational attainment (Myende, 2014).

The historically present deprivation of South Africa’s rural areas makes quality education not only an imperative but also an issue of social justice issue and citizenship (Odora-Hoppers, 2004). Teacher professional development in the rural Hantam environment was contextualized by building on existing community partnerships and integrating Khoi-San indigenous knowledge into STEM classrooms. The community based approach informed the design of teacher professional development aligned with the educational needs of the community. Embodied, distributed, situated cognition provided a foundation to explore the interaction between physical and social environment that is active in indigenous knowledge contexts. The use of embodied ways of knowing decolonizes ways of knowing and practicing science and mathematics in STEM classrooms. The embodied perspective also provided a lens to explore the affordances of cultural assets in contextualizing teacher professional development. The contextualized teacher professional development approach presented in this paper strengthened partnerships between the community and schools aimed at improving teacher competencies and making science and mathematics instruction relevant to the learners. Contextualized teacher professional development has the potential to harness knowledge

assets and cultural resources present in rural communities, making social transformation a possibility.

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PHYSICAL SCIENCES PRE-SERVICE TEACHERS' REPRESENTATIONS OF INQUIRY- BASED PRACTICAL WORK FACILITATION

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ABSTRACT: Inquiry through practical work is one of the instructional strategies that physical sciences pre-service teachers learn how to facilitate during methods courses. An exploratory case study involving thirty-five physical sciences pre-service teachers was undertaken to probe the kinds of inquiry-based practical work facilitation representations they could generate in simulated teaching conditions. Data were collected by means of video-recorded lessons and lesson plans that were analysed through constant comparison techniques in order to build themes. The pre-service teachers were not prepared to facilitate inquiry through practical work because the representations they developed were teacher-centred. The findings suggested that the pre-service teachers could not develop objectives for inquiry but used purposes of practical work such as strengthening conceptual understanding, practising process skills, making learners work in groups and explaining scientific phenomena based on evidence. The pre-service teachers also displayed content misconceptions, poor mastery of process skills and misconceptions about inquiry-based practical work facilitation. The study details specific examples of tensions and challenges that the pre-service teachers faced. The study recommends that these specific tensions should be taken in to account when developing pedagogical frameworks to guide pre-service teachers when they plan and facilitate inquiry-based practical work for learners.

Keywords: Inquiry-based practical work; inquiry-based practical work facilitation; physical sciences pre-service teachers; simulated teaching.

INTRODUCTION

One of the aims of science teaching methods courses is to expose pre-service teachers to effective teaching and learning strategies for the school curriculum. The pre-service teachers are expected to learn how to teach science using inquiry strategies among other teaching approaches. Teachers are known to display varied understandings of what constitutes teaching science as an inquiry (Barrow, 2006). In China, Gao and Wang (2014) observed that two chemistry teachers developed different strategies to implement inquiry despite using the same syllabus. In addition, pre-service and in-service teachers are reported to be struggling with internal conflicts as they negotiate contextual factors in the implementation of inquiry-based science (Ramnarain & Hlatswayo, 2018; van Uum, Verhoeff & Peeters, 2016). In Spain, García-Carmona, Criado and Cruz-Guzmán (2017) concluded that pre-service science teachers display a number of shortcomings when planning for inquiry-based practical work. Kidman (2012) observed that Australian teachers were not ready to implement the inquiry-based science curriculum due to a myriad of factors. These impeding factors range from teacher identities to the lack of facilities, resources and support (Kidman, 2012, Cheung, 2007). Crawford (2007) asserts that pre-service teachers' representation of teaching science as an inquiry varies from teacher-centred approaches to innovative, open and even full inquiry. For science teacher educators, it is always important to establish how pre-service teachers represent inquiry-based science facilitation after completing the relevant methods courses as a way of participating in the scholarship of teaching and learning. The varied and oftentimes, erroneous representations of inquiry necessitates understanding how science teachers develop their understanding of inquiry-based teaching.

Despite the observed challenges, in earlier decades Crawford (1999) already believed that it is realistic to expect pre-service teachers to be able to facilitate inquiry-based science for learners. One of the ways through which inquiry can be facilitated for learners in science is through practical work. However, literature reports that in a similar way to inquiry-based science, pre-service teachers experience internal and external conflicts as they negotiate the implementation of practical work in science classrooms (Kim & Tan, 2011). What seems to be important for science teacher educators who are responsible for teaching methods courses is to further establish the nature of conflicts and tensions experienced by pre-service teachers. The need to establish the nature of tensions and conflicts experienced by pre-service teachers prompted the conceptualisation of this study. The understanding of the nature of challenges experienced by the pre-service teachers in particular contexts may constitute an important step in the development of frameworks to guide pre-service teachers as they learn how to facilitate inquiry-based practical work. The pedagogical frameworks to support pre-service science teachers as they learn how to facilitate inquiry-based practical work remain unclear in the literature. In an attempt to elucidate some pedagogical frameworks, some researchers have developed rubrics to rank inquiry-based practical work from simple to complex (Herron, 1971; Cheung, 2007; Bretz & Fay, 2008). Llewelyn (2013) also describes a series of actions that constitute the cycle of inquiry that teachers can use in the science classrooms. Similarly, other researchers consider learners to be engaged in inquiry through practical work when they practise process skills. Barrow (2006) says inquiry may be regarded as a set of skills that Abd-el-Khalick et al. (2004) exemplify as identifying problems, formulating questions, designing and conducting investigations and formulating, communicating and defending hypotheses, models and explanations. Ozdem, Ertepinar, Cakiroglu and Erduran (2013) describe a four domain pedagogical framework that can be used to guide teachers. The four domains are the conceptual, epistemic, social and procedural domains. These frameworks will be further discussed under the theoretical framework section.

This present study represents one of a series of preliminary explorations designed to establish pre-service teachers' understandings of inquiry-based practical work facilitation as a part of a three-phase design-based research project to develop a model to prepare pre-service teachers. It is inherent to design-based research to have different stages for which data are collected and the findings reported (Andriessen, 2006). The purpose of this particular study is to explore physical sciences pre-service teachers' representations of inquiry-based facilitation. The study was conducted at one South African university. Accordingly, the following research question was asked, *how do physical sciences pre-service teachers represent inquiry-based practical work facilitation?*

THEORETICAL FRAMEWORK

A pedagogical framework that can guide teachers and pre-service teachers in the facilitation of inquiry may consist of four pillars. These are the conceptual domain, the epistemic domain, the social domain and the procedural domain (van Uum et al., 2016). The conceptual domain encompasses science as a body of knowledge. The epistemic domain is represented by belief systems of what scientific knowledge is and how it is generated. Ozdem et al. (2013) address the epistemic domain by looking at argumentation schemes generated by pre-service teachers during inquiry-based laboratory activities. The study recommends that pre-service science teachers should be encouraged to integrate argumentation into the teaching and learning strategies for their future classrooms. For science education, argumentation is defined "as a discursive practice through which scientific knowledge claims are justified or evaluated based on empirical or theoretical evidence" (Ozdem et al., 2013, p. 2562). The social domain of the pedagogical framework draws from social-constructivist theories, such as those by Vygotsky (1978), in which learning is viewed as a social activity. Van Uum et al. (2016) mention that

during practical work activities learners can work in groups to promote collaboration. Similarly, researchers in science and science education may collaborate during projects and that they are constantly building on each other's theories (ibid). The procedural domain involves the steps in the inquiry cycle during practical work that include the posing of the investigative question, conducting the investigation and the drawing of the conclusions. Llewelyn (2013) outlines the steps of an inquiry cycle, which starts with an introduction in which teachers introduce the topic and assess prior knowledge. The introduction is followed by an exploration stage in which questions are raised and explored in order to select a hypothesis to test. An investigation to test the hypothesis is designed and conducted. The collected data are analysed and organised into relationships in order to draw conclusions. The results are presented and communicated and finally the new knowledge is compared to the prior knowledge during a process of deepening and broadening. The pre-service science teachers should learn to facilitate this kind of inquiry process for learners.

Inquiry-based practical work can be placed on a continuum because it can be conducted at different levels of complexity. Accordingly, rubrics have been developed that enable researchers to place inquiry activities on continuums that range from simple to complex. These kinds of rubrics can guide science teachers when facilitating inquiry-based practical work. Herron (1971) developed one such rubric and it has four levels. The lowest level of inquiry is referred to as confirmation inquiry and is used to verify or confirm results that are known beforehand. García-Carmona et al. (2017) say that this type of inquiry is used to strengthen conceptual understanding and allows learners to practise the acquisition of process skills. The level of inquiry that follows on the continuum is structured inquiry. For this kind of inquiry, the teacher gives the investigative question and the procedure of the experiments to the learners. However, the learners should be able to analyse the data collected and draw conclusions. Guided inquiry follows the structured inquiry on the continuum. In guided inquiry, learners use a question or problem presented to them by the teacher to design and conduct investigations. Open inquiry is ranked highest in the rubric. The learners have autonomy of the whole inquiry process from question posing, designing and conducting of the investigation up to the drawing of conclusions. Equipped with the knowledge of the rubrics, science teachers can plan the practical work activities for the learners targeting specific levels of inquiry. In spite of the available theoretical knowledge of how to facilitate inquiry-based practical work, successful implementation is reportedly very challenging for science teachers due to a myriad of reasons (Cheung, 2007). A need arises to develop frameworks that teachers can use in order to implement inquiry-based practical work successfully.

The inquiry cycle by Llewelyn (2013) was used as an analytical framework because it is more comprehensive since it incorporates the inquiry level rubric by Herron (1971). The actions of question posing, experiment design and solution articulation are contained in the cycle. The cycle also reflects the four domains (conceptual, epistemic, social and procedural) by van Uum et al. (2016) of the pedagogical framework to guide teachers as they facilitate inquiry in the science classrooms. The cycle is procedural in nature and allows for social interaction (learner-learner and teacher-learner). Every inquiry process seeks to explore particular scientific concepts and it represents an epistemic position of how scientific knowledge is generated.

METHODOLOGY

This qualitative study sought to explore how pre-service physical sciences teachers represented inquiry-based practical work facilitation in simulated conditions. Simulated teaching is a powerful tool to improve pre-service teachers' teaching skills (Frederking, 2005). The performance and behaviour developed during simulated teaching is transferable to real classrooms. Data were collected by means of five video-recorded lessons and five lesson plans. Convenience sampling was

used to select 35 pre-service teachers out of a physical sciences methods course class with 86 students. The methods course class consisted of 75 Postgraduate Certificate of Education (PGCE) students and 11 third year Bachelor of Education students. The 35 students had responded positively to an invitation that was extended for them to participate in the study after the study had obtained ethical clearance from the university. Out of the 35 participants, 30 were PGCE students and the remaining 5 were BEd students. The pre-service teachers were requested to form groups that consisted of seven members. Five groups were formed. The groups of pre-service teachers were instructed to collaboratively plan a lesson that would represent how they would facilitate inquiry through practical work in physical sciences. The use of a collaboration approach to plan the lesson was in line with the constructivist theme of the science methods course in order to get a socially co-constructed view of inquiry facilitation. We further asked them the question, how can you improve a practical work activity you observed or facilitated during your teaching practice in the schools by incorporating inquiry strategies? A further instruction was given for them to formulate lesson objective(s) using the Curriculum Assessment and Policy Statement (CAPS) physical sciences syllabus and select the materials and resources they would need in order to present the lesson to a class of learners. The pre-service teachers were also instructed to use one of the group members as a teacher who would present the lesson. In the discussions that follow, the pre-service teacher who presented the lesson may at times be referred to as “the teacher”. One other group member would video-record the lesson. The other five members of the group would participate as learners. The video-recorded lessons were submitted to the researcher together with a lesson plan. The lesson plans were in the form of PowerPoint presentations that the teachers used during lesson delivery. The groups were numbered from 1 to 5 and they presented the cases that were used to build themes on how pre-service teachers represent practical work facilitation.

Data Analysis

The video-recorded lessons were played and observed to capture the teacher and learner activities into a transcript. The video transcript and the lesson were organised into units of analysis of how inquiry-based practical work was facilitated by each of the five groups of participants using constant comparison techniques. The units of analysis were summarised in Table 1 to allow for further constant comparison and the building of themes. Table 1 below shows the lesson topics and lesson objectives selected and used by the groups. The table also summarises the teacher and learner actions during the different stages of the inquiry cycle.

Table 1: The facilitated practical work activities

Group	1	2	3	4	5
Practical work activity facilitated	Separation of mixtures	Testing for acidity and basicity	Ohm's Law	The cleaning action of soap	States of matter
Lesson objectives	Distinguish between heterogeneous and homogeneous mixtures Separate mixtures	Identify acids and bases using indicators Measure acidity and basicity on a pH scale	Verify Ohm's Law	Demonstrate the surfactant action of soap (dish soap)	Distinguish the three states of matter
Introduction and exploration	Teacher uses questioning techniques for the class to define the terms heterogeneous and homogeneous mixtures Teacher explains how to separate some of the mixtures	Teacher conducts an exposition on the basic facts about acids and bases Learners write a short test on the basic facts	Teacher conducts an exposition on the law stating that current is directly proportional and shows the shape of the graph of current plotted against voltage	The teacher conducts an exposition on the role of intermolecular forces in keeping the molecules of one substance held together	Teacher explains the steps of the scientific method and urges learners to formulate a hypothesis to a question "What happens when a solid is mixed with a liquid?" No hypothesis is suggested
Designing and conducting the investigation	Designed by the teacher Demonstrated by the teacher Learners repeat the experiment in groups (filtration of a water and sand mixture, separating a mixture of beans and sand by hand)	Designed by the teacher Learners use an instruction sheet to conduct the experiment in groups (use litmus paper to test household chemicals and compare the colour on a pH scale)	Designed by the teacher Demonstrated by the teacher Learners repeat the experiment in groups Teacher collects data from the learners' experiment	Designed by the teacher Demonstrated by the teacher (The milky rainbow formed when a cotton bud covered with dish soap is dipped into a bowl of milk spotted with different colours of food colouring) Learners repeat the experiment in groups experiment in groups	Designed by the teacher (vinegar is mixed with bicarbonate of soda; CO ₂ is produced) Learners follow instructions from the teacher as they conduct the experiment in groups
Conclusion and communication	Teacher handed out papers with questions that learners responded to as a post-experiment exercise.	The learners and teacher confirm what they already knew about the base and acidic nature of the household chemicals No further communication	Teacher uses the computer to draw the current vs voltage graph confirming what was already known No further communication	Teacher facilitates a discussion for learners to explain what they observed happening focusing on the role of food colouring and the dish soap in the experiment	Learners observe that matter can exist as a solid, liquid and a gas No further communication
Researcher comments	A misconception was noted (The teacher presented the sand and water mixture as an example of a homogeneous mixture)	The practical work activity was used to verify the facts that were already known.	A verification experiment conducted to emphasise the importance of using evidence to explain scientific phenomena.	Learners to formulate a hypothesis (they were not able to formulate any)	The teacher poorly formulated the investigative question.

FINDINGS

Five themes were built from the data analysed using constant comparison techniques. The units of

comparison were the five sets of data collected from the five groups. The five themes that were used to describe the pre-service teachers' representations of inquiry-based practical work facilitation were (1) facilitation of the inquiry cycle through transmission instructional strategies; (2) use of practical work to strengthen conceptual understanding (3) emphasising some of the process skills (4) facilitation of learner collaboration and (5) display of misconceptions and poor mastery of the process skills.

Facilitation of the inquiry cycle through transmission instructional strategies

The inquiry cycle may be summarised by dividing it into seven stages namely, introduction, exploration, designing the experiment, conducting the experiment, conclusion, presentation/communication and finally deepening/broadening of knowledge. Only the first five stages were evident during the observed lessons for all the groups as can be seen in Table 1. The presentation/communication and the deepening/broadening stages were not planned for or implemented during the inquiry-based practical work facilitation. The five stages were facilitated through transmission instructional strategies. The introduction and exploration stages were conducted through teacher presentations to introduce the topic and notify the learners of the experiment that they would be conducting. The teacher in all five groups designed the experiments. The experiment procedures were explained to the learners in three ways. The teachers for Groups 1, 3 and 4 performed demonstrations of the experiments, which were later repeated by the learners. Group 1's teacher provided a work sheet with instructions for learners to follow. Finally, Group 5's teacher was giving the instructions verbally for the learners follow.

Use of practical work to strengthen conceptual understanding

The lesson objectives for groups 1, 2, 3 and 5 from the lesson plans indicated that the pre-service teachers were primarily concerned with the learners' mastery of the science content as shown in Table 1. The introduction section of the lessons for Groups 1, 2, 3 and 4 were in the form of teacher expositions that went beyond ascertaining prior knowledge. The content was taught using direct transmission and the practical work that followed served to confirm what the learners were told already as a way of strengthening their understanding of the concepts. The finding seems to suggest that the pre-service teachers put more emphasis on the mastery of content than the way of knowing by inquiry. None of the objectives were directed at learning the steps or actions of inquiry.

Emphasis on some of the process skills

The pre-service teachers also represented inquiry-based practical work as learners' ability to engage in some of the process skills. After introducing the lesson topic and establishing the three states of matter, Group 5's pre-service teacher took time to explain the steps of the scientific method to the learners. Similarly, Group 4's pre-service teacher said, "You should be able to develop a hypothesis and you should be able to predict. For that you need to observe and make a conclusion." The steps form part of the process skills for inquiry-based practical work. Of all the process skills, the need to be able to formulate hypotheses was emphasised. Although the pre-service teachers mentioned the need to formulate hypotheses, they were not able to facilitate the formulation to be conducted by learners. It also seemed significant to the pre-service teachers to show the importance of explaining scientific phenomena based on evidence gathered during the experiments.

Facilitation of learner collaboration

The lesson plans and the lesson observations indicated that all the pre-service teachers organised the learners in groups before they could start conducting the experiments. Making learners work in groups seemed to be very important to the pre-service teachers' representation of inquiry-based practical work. Group 1's teacher emphasised that one of the aims of the lesson was for the learners to work in groups. She instructed, "We should be able to work as a group to collect and analyse information and be able to get results. You must work as a group and not individually."

Display of misconceptions and poor mastery of the process skills

A number of challenges could also be noted during the inquiry-based facilitation. First, the pre-service teachers were not able to facilitate the formulation of hypotheses although they pointed it out to the learners that they should not be able to do so. The pre-service teachers ended up suggesting a hypothesis for the learners. In Group 5 the teacher asked, "What happens when a solid is mixed with a liquid?" in an attempt to urge the learners to formulate a hypothesis. The solid and the liquid that the teacher was referring to were powdered bicarbonate of soda and vinegar. None of the learners could offer any hypothesis possibly due to the poor formulation of the question. It could be noted that the teacher also struggled to properly formulate an investigative question. Secondly, the pre-service teacher in Group 1 presented a heterogeneous mixture (sand and water) as an example of a homogeneous mixture and even the learners themselves who were also pre-service teachers could not pick up the content error.

DISCUSSION AND CONCLUSION

The study set out to explore physical sciences pre-service teachers' representations of inquiry-based practical work facilitation in the context of one South African university. The study was set against a background in which literature asserts that it is very challenging for teachers and pre-service teachers to facilitate inquiry in science classrooms on the one hand (Ramnarain & Hlatswayo, 2018; van Uum, Verhoeff & Peeters, 2016). On the other hand, literature also establishes that it is realistic to expect pre-service teachers to begin to plan and facilitate inquiry activities in science classrooms (Crawford, 1999). Additionally, literature also asserts that teachers and pre-service teachers interpret the facilitation of inquiry in different ways (Barrow, 2006). Being a science teacher educator it was worth the while for me to understand how a group of pre-service teachers who had gone through a methods course were able to facilitate inquiry through practical work in the context of the South African university.

In describing the pre-service teachers' representations of inquiry-based practical work facilitation five themes were built. First, a tension was observed in which the pre-service teachers facilitated an activity that was supposed to be of an inquiry nature through transmission teaching strategies. The transmission strategies include teacher expositions and teacher demonstrations. In comparison with other international findings by Kidman (2012), there is an agreement that teachers may find the facilitation of inquiry very challenging. Unlike other international findings in which pre-service teachers were observed to be able to facilitate innovative and open forms of inquiry (Crawford, 2007), the pre-service teachers in this study used teacher-centred approaches only. A closer analysis of the findings seems to indicate the pre-service put a lot of emphasis on some purposes of practical work than the essence of facilitating inquiry through practical work. Accordingly, the pre-service teachers used parts of the inquiry cycle (introduction, exploration, designing and conducting of the investigation and conclusion) to strengthen the learners' understanding of concepts that were known beforehand. This form of inquiry-based practical work facilitation appears on the established rubrics as confirmatory inquiry (Herron, 1971; Bretz & Fay, 2008; Garcia-Carmona et al., 2017). Garcia-Carmona et al. (2017) further elucidates that the confirmatory inquiry also affords learners the opportunity to acquire the process skills. The purposes of confirmatory inquiry also establish it as an important instructional strategy despite being ranked lowly on the inquiry continuum. It could be noted that the pre-service teachers did not explore the last two steps of the inquiry cycle, which are presentation/communication and deepening/broadening.

The pre-service teachers also knew that learners had to learn some of the process skills that they summarised as steps of the scientific method. The findings also suggest that the pre-service representations of inquiry-based practical work facilitation involved the organisation of learners in groups to enable collaboration and cooperation. This representation displays epistemic positions

that are sympathetic to the social nature of learning according to learning theories of constructivism (Vygostky, 1978). However, the teacher-centred facilitation of the inquiry process denied the learners the opportunity to participate optimally in the construction of knowledge. One other important finding about the pre-service teachers' representations of inquiry-based practical work facilitation is in the form of a major challenge. The pre-service teachers displayed misconceptions in the content domain. The pre-service teachers also displayed a poor mastery of the process skills (procedural domain). According to van Uum et al. (2016), the content and procedural domains constitute two out of four important domains of a pedagogical framework to support and guide teachers when they are facilitating inquiry-based practical work. The study by Chabalengula, Mumba and Mbewe (2012) with 91 elementary pre-service science teachers concluded that the participants had a limited conceptual understanding of science process skills, which according to Anderson (2002), form an important part of scientific inquiry. This study elucidated some of the specific tensions that physical sciences pre-service teachers grapple with in the space of pedagogical frameworks to facilitate inquiry-based practical work. The tensions lead to a major misconception of representing inquiry-based facilitation using transmission strategies, denying the learners the opportunity to engage in inquiry. Since the pre-service teachers' facilitation of inquiry-based practical work, the study recommends the development of a pedagogical framework that prepares pre-service teachers to explore the levels of inquiry facilitation beyond confirmation and verification. The framework should support them on how to cede control of important inquiry actions such as question posing, designing and conducting the investigation, drawing conclusions, communication and deepening of knowledge to the learners. The framework should also prepare the pre-service teachers to guard against bringing misconceptions on content into the science classrooms.

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TECHNOLOGY EDUCATION PAPERS

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EMBEDDING DIGITAL CAPABILITY DEVELOPMENT INTO THE CURRICULUM IN GHANA: NOT THERE YET

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ABSTRACT: In this paper, we report on the digital experiences of students at a dual-mode higher education institution in Ghana. Recognizing the role of digital technologies in becoming competitive in an increasingly globalized economy, Ghanaian authorities have embarked on a number of initiatives to support the development of the digital skills and capabilities of its student body system to enhance learning and to improve their digital skills for the job market. However, some evidence exists that despite the several initiatives and massive investment into digital skills development, students in Ghana are still grappling with the acquisition of the kinds of 21st-century skills that are needed for enhanced learning and for the modern workplace. The question thus arises whether Ghanaian HEIs are sufficiently developing the digital capabilities of its students. The research used the 'Digital on your course' dimension of the JISC Digital Tracker instrument to determine the digital experiences of students. Census sampling targeted all final-year students at a selected HEI. The online survey reached 14255 students, and 803 students (5.6%) responded. The results show that there is a limited attempt to embed the development of digital skills into academic disciplines and that technology is not used to communicate and collaborate, to solve problems, and to create digital artefacts. The limitation of the findings is that the results of only one institution is reported.

Keywords: Digital literacies; digital capabilities; Ghana; Ghana higher education

INTRODUCTION

The accelerating pace of the use of digital technology is transforming the workplace, and directly impact the skill requirement for modern jobs. The use of technologies such as artificial intelligence, 'internet of things' and robotics may gradually replace most of today's routine jobs (Fadel, Bialik & Trilling, 2015), and it further emphasises the need for graduates to 'upskill' and 'up-tool' should they want to remain relevant in the workplace (Chui, Manyika, & Miremadi, 2015). The need for graduates to develop digital capabilities for collaboration and communication persist to be important as the ecosystems of business are changing (World Economic Forum, 2016). Therefore, the challenge remains for governments, employers, policy makers, educators and students alike to identify the digital skills that are relevant for not only today, but which will also meet the demands of the changing workplace. Due to restrictions on page length imposed for this paper, the research question that this paper responds to only is therefore: What are the digital experiences of students at an HEI in Ghana considering the, 'Digital on your course', dimension of the Digital Tracker instrument?

To achieve this, we first unpack the concept 'digital capability development'. Then, we briefly outline the imperative on Higher-Education Institutions (HEIs) to develop the digital capabilities of students in order for them to become productive members of a digital economy. We emphasise that it is particularly important for developing countries like Ghana to develop digitally capable students. We then describe the research methods that were used to conduct a survey among students in dual mode HEI in Ghana, using the JISC 'Digital Tracker' tool, and report the results of that survey. Finally, we use the results of the survey to make recommendations for student digital capability development.

CONCEPTUALISING DIGITAL CAPABILITY DEVELOPMENT

According to Beetham and Sharpe (2010), “digital literacy is developed on a set of technology-based-practices which begins from access to technology and functional skills to higher level capabilities”. Further, the ‘European Computer Driver’s License, (EDCL) asserts that educational institutions need to invest in equipping classrooms with digital technologies and e-learning solutions to unleash a generation of digital natives. This is necessary to propel students for future jobs that which now requires more of digital skills (Raja & Christiaensen, 2017). Educators should identify areas of opportunities that allow students to use digital tools and resources to look for information online (academic sources including citing and referencing), use simulations for learning, create portfolios of their learning, use online polls or quizzes, as well as communicate and collaboratively use digital technologies. Such activities should challenge students to an appropriate degree of creating a digital artefact (JISC, 2017).

The best method to develop digital capabilities is to embed the technologies and skills in the context of the academic curriculum (Becker, Clark & Collins, 2011; Bohannon, Arnett & Greer, 2017; Raven, 2012) and across all disciplines rather than a strand within technology (Beetham & Sharpe, 2013; Forrest, Hagemann & Rendall, 2017; Soland, Hamilton & Stetcher, 2013). Bolstad, Gilbert, Vaughan, Darr, and Cooper (2006) emphasise that digital capabilities should be an integral part of all 21st-century skills and key competencies and not sit outside learning. They continued that when taught in isolation digital literacy skills will lose its context for learning across the curriculum for collaboration and creativity. For example, within the learning context, educators can set digital activities or assessments that draw on authentic digital practices such as shaping a presentation and workshops around digital literacies, designing authentic activities that allow the use of technology and add value to students’ learning. It is therefore important that digital literacy be situated within professional and academic context and influenced by a wide range of practices such as digital collaboration, searching of information, creation of portfolio (JISC, 2017).

The importance of digital capability development in the developing world

Developed countries have been leading the drive to develop students’ digital capabilities since they identified digital competence as essential for workers to thrive in today’s digital society (Carretero, Vourikari & Punie, 2017; Coldwell-Neilson, 2017). Countries such as the UK have made significant progress towards developing digital capability frameworks, policies and programmes, to ensure that students living all level of education especially, higher education and further educations institutions, are equipped with digital skills and capabilities that will enable their graduates to participate in the globalized digital economy. In Sweden, the government has made digital skills a core basic competency to be integrated in all aspects of the academic curricula (OECD, 2016a).

The necessity of developing the digital capabilities of students also extends to countries in the developing world, including Ghana. Over the last two decades, the government of Ghana recognised the importance of developing the digital capabilities of students at all levels of the Ghanaian education system to enhance learning, improve job skills and ultimately ensuring prosperity (MOE, 2015; Wilson, Tete-Mensaha & Boateng, 2014). This assertion reflects in the Ghana Poverty Reduction Strategy Paper (GPRS I & II) and the Education Strategic Plan (ESP) 2003-2015 which came into existence before the national Information and Communication Technology for Accelerated Development (ICT4AD) policy. The GPRS and the ESP were indicative of the Ghana government effort to increase awareness about ICTs as a means of reducing poverty in the country (Mangesi, 2007).

Recently, education policies were revised to govern the implementation of ICTs in schools and higher education institutions (HEIs). The aim of these revisions was to respond to the nation’s need to develop the economy and to ensure that institutions produce graduates who are ready for the labour market (MoE, 2015). Subsequently, the government of Ghana and other stakeholders in education invested heavily in digital training and provisioning of digital technologies in higher education

institutions. HEIs were guided to embed the development of the digital capabilities of students into their curricula in authentic contexts to improve the digital and entrepreneurial skills of the students to enable them compete in the global job market (MoE, 2008; MoE, 2015). HEIs were to ensure that the curricula are providing the opportunity for students to build 21st century skills to meet the demands of a digitally disrupted workplace. However, many of the digital capabilities programs and policies in the universities resulted in programmes to develop students' digital capabilities by teaching these digital skills as a separate course (Gyamfi, & Ryberg, 2012; Wilson, Tete-Mensah & Boateng, 2014). Therefore, we assert that despite the implementation of the policies and introduction of the ICT courses, students are still grappling with acquiring the 21st-century skills needed for learning and to succeed in the workplace (Tagoe, 2012). Whereas improved access to digital technologies could be considered essential to bridge the digital gap, research indicate widespread access to and the use of digital technologies alone will not improve student digital capabilities. Research generally indicate that when digital technologies are integral to good teaching practice, it *"will open new doors to enhance learning and digital skills"* (McLachlan, Craig, & Codwell-Neilson, 2016; OECD, 2016b). According to Alexander, Adams Becker, Cummins and Hall Geisinger (2017), students develop digital capabilities best in the context of the academic practices. Therefore, we argue for programmes that embed the use of digital technologies into academic disciplines and that are reflective of the complexity of digital practices within context.

METHODOLOGY

Instrument

This study uses the JISC 'Digital Tracker' survey instrument to establish the extent to which the development of the digital capabilities of students at HEIs are embedded in the teaching of academic disciplines. The Digital Tracker survey instrument which determines students' digital experiences at

HEIs (<https://www.jisc.ac.uk/rd/projects/student-digital-experience-tracker>) was deemed appropriate to assess the extent that HEIs develop the digital capabilities of students. The instrument uses four dimensions aptly labelled 'You and your digital', 'Digital at your Uni', 'Digital on your course', and 'Attitude to digital learning'. Due to page limitations for this paper, the 'Digital on your course' dimension of the survey was selected to report on. This dimension of the 'Digital Tracker' comprises multiple choice response type items that require responses to three point Likert-type scale options with "weekly or more" at the high end of the scale, and "never" at the lowest end (JISC, 2018). JISC validated the instrument by piloting it among 22000 higher and further education students in 72 institutions in the UK and 5000 students in 10 international institutions (Newman & Beetham, 2017). For the purposes of this paper, the questionnaire was piloted among 30 undergraduates at a comparable higher education institution in Ghana to determine the extent to which the items made sense for students in Ghana, and how easy these students found completing the survey (see Selwyn & Gorard, 2015). As no issues were reported, no amendments were made to the final instrument.

Settings and Participants

A single dual-mode HEI in Ghana was targeted and 'census sampling' identified all final-year students at the selected HEI. Final-year students were targeted as they would have had the longest enrolment at the institution and would be in the best position to accurately report on the digital capability development efforts of the institution. The age range of the respondents ranged from 19 to 62 (mean age = 27.5, SD =6.001). Table 1 displays the disaggregated frequency analysis of the sample by gender, level of study, field of study and mode of study. There was a low representation of female students (35.4%) in comparison with the national average of 51% (Ghana Statistical Service, 2016). Full-time students comprised 52.4% of the responses.

Table 1. Disaggregated demographic data

		<i>n</i>	%	
Gender	Male	517	64.6	
	Female	283	35.4	
Level of study	Graduate	119	14.9	
	Final Year Undergrad	681	85.1	
Field of study	Agriculture	37	4.6	
	Biological and Biomedical Sciences	36	4.5	
	Business	269	34.9	
	Communication and Journalism	32	4.0	
	Computer Science	28	3.5	
	Education	158	19.8	
	Legal Studies	41	5.1	
	Liberal Arts and Humanities	28	3.5	
	Medical and Health Professions	40	5.0	
	Physical Sciences	23	2.9	
	Psychology	98	12.3	
	Mode of study	Distance Learner	381	47.6
		Full-Time Study	419	52.4

Data Collection

Data was collected online using JISC ‘Online surveys’ (formerly BOS). The online survey reached 14255 students, and 803 students (5.6%) responded. We sent the respondents email through the university’s email system telling them about the survey. The content of the email included hyperlink to the survey website, which they need to click to open the questionnaire for participation. The respondent simply click submit upon completion to submit the responses to the Online surveys database. The responses were kept in the ‘Online survey’ database for analysis

Data Analysis

The data was analysed by the ‘Online survey’ tool that automatically calculated basic descriptive statistics and presented data visually as tables. In addition, SPSS version 25 was used to perform other statistical analyses. T-test statistical test tool was used to determine whether inferential relationships exist among the students by mode of study (for example: digital experiences of distance students and full-time students in the university).

RESULTS

In the following sections, the results of the survey are presented as they relate to the items that were included on the Digital Tracker and the objectives of the research. First, we present the data on the extent of students’ engagement with digital technologies during their enrolment at the institution.

Extent of students’ engagement with digital technologies in context of their subject disciplines

The most frequent digital activity by students in the academic courses are to find information (70%, n=560). This result is captured in Table 2, as well as the responses to the items on working online with others, using games or simulations, using online assessment tools, creating digital records or portfolios of learning, and producing work in digital format other than word processing documents or presentations.

Table 2: Students' digital experience in modules

	Weekly more	or	Monthly or less	or	Never	
	Freq	%	Freq	%	Freq	%
Find Information online	560	70	154	19.3	86	10.8
Work online with others	271	33.9	270	33.8	259	32.4
Use an educational game or simulation for learning	219	27.4	245	30.6	336	42
Use a polling device or online quiz to give answers in class	186	23.3	234	29.3	380	47.5
Create a digital record/portfolio of learning	179	22.4	224	28.0	397	49.6
Produce work in digital formats other than Word/PowerPoint	204	25.5	254	31.8	342	42.8

Overall, distance students reported slightly higher frequencies of using computers in the context of their academic activities.

Student digital experiences by mode of study

In Table 3, the experiences of distance learners and full-time students are tabulated. Independent-samples t-tests were conducted in order to determine whether data regarding the variables identified in Table 2 and Table 3 could be proven to be statistically different between distance education students and full-time students in the institution. The results of the analysis are tabulated in Table 3.

Table 3: Student digital experiences by mode of study

	Mode of your study in the University	N	Mean	Std. Dev	t	df	sig																																																								
Find information online	I am a distance learner	381	1.55	0.772	5.758	675.96	0.00																																																								
	I am a full-time student	419	1.28	0.544				Work online with others	I am a distance learner	381	1.95	0.834	-1.155	798	0.248	I am a full-time student	419	2.02	0.796	Use an educational game or simulation for learning	I am a distance learner	381	2.14	0.839	-0.235	798	0.815	I am a full-time student	419	2.15	0.804	Use a polling device or online quiz to give answers in class	I am a distance learner	381	2.25	0.834	0.405	798	0.686	I am a full-time student	419	2.23	0.780	Create a digital record / portfolio of your learning	I am a distance learner	381	2.26	0.816	0.512	798	0.609	I am a full-time student	419	2.29	0.794	Produce work in digital formats other than Word/Powerpoint	I am a distance learner	381	2.26	0.794	2.928	298	0.004
Work online with others	I am a distance learner	381	1.95	0.834	-1.155	798	0.248																																																								
	I am a full-time student	419	2.02	0.796				Use an educational game or simulation for learning	I am a distance learner	381	2.14	0.839	-0.235	798	0.815	I am a full-time student	419	2.15	0.804	Use a polling device or online quiz to give answers in class	I am a distance learner	381	2.25	0.834	0.405	798	0.686	I am a full-time student	419	2.23	0.780	Create a digital record / portfolio of your learning	I am a distance learner	381	2.26	0.816	0.512	798	0.609	I am a full-time student	419	2.29	0.794	Produce work in digital formats other than Word/Powerpoint	I am a distance learner	381	2.26	0.794	2.928	298	0.004	I am a full-time student	419	2.09	0.815								
Use an educational game or simulation for learning	I am a distance learner	381	2.14	0.839	-0.235	798	0.815																																																								
	I am a full-time student	419	2.15	0.804				Use a polling device or online quiz to give answers in class	I am a distance learner	381	2.25	0.834	0.405	798	0.686	I am a full-time student	419	2.23	0.780	Create a digital record / portfolio of your learning	I am a distance learner	381	2.26	0.816	0.512	798	0.609	I am a full-time student	419	2.29	0.794	Produce work in digital formats other than Word/Powerpoint	I am a distance learner	381	2.26	0.794	2.928	298	0.004	I am a full-time student	419	2.09	0.815																				
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DISCUSSION

Students' digital experience in modules

Table 2 indicates that the most frequent digital activity prevalent in the academic courses 'finding information'. On average across all disciplines, 70% of students reported making widespread and frequent use of digital technology formerly for finding information during class activities. This represents a large proportion of students – although 10.8% of the students reported never using digital tool for finding information in the classroom. 32.4% of the students reported never working online with others. Just 27.4% of the students indicated that they use educational games or

simulations at least weekly for class activities. On average slightly few students (23.3%) of the students said that they do online quiz or use polling systems to give answers in class at least weekly, 49.6 % indicated that they have never created a digital record/portfolio in their learning, and 25.5% of reported that they have produced digital artefacts other than Word/PowerPoint during class activities.

Student digital experiences by subject discipline and mode of study

Table 3 shows the differences in response among distance learners and full-time students. An independent-samples t-test was conducted to compare the use of digital technology in context of their academic activities. It was found that there was significant difference in response, $t(675.96) = 5.76$, $p < 0.05$, in the use of digital technology to “find information online” between distance learners ($M = 1.55$, $SD = 0.772$) and full-time ($M = 1.28$, $SD = 0.544$). The magnitude of the differences in the means (mean difference = 0.27, 95% CI: 0.181 to 0.368) was very small (0.040). The results also recorded significant difference in response to the use of technology to “Produce work in digital formats other than Word/Powerpoint”, $t(798) = 2.928$, $p < 0.05$, between distance learners ($M = 2.26$, $SD = 0.794$) and full-time ($M = 2.09$, $SD = 0.815$). The magnitude of the differences in the means (mean difference = 0.17, 95% CI: 0.06 to 0.279) was very small (eta squared = 0.011).

No difference was found between the response of full-time and distance learners with respect to other digital activities which included “work online with others”, “use an educational game or simulation for learning”, “use a polling devices or online quiz to give answers in class” and the use digital technology to create record / portfolio of learning”.

CONCLUSION

This paper explored higher education students experience with digital technology in context of their academic curricula. The most common digital activity in the classroom involved the use of technology to find information online. It was also identified that students were less likely to use technology to produce digital artefacts, collaborate online with others, create digital portfolio or complete assignments and quizzes online. Perhaps the most notable aspect of this paper was the differences in digital experience by mode of study. The paper identified that distance learners use digital technology more to find information in context of their academic courses compared to full-time students.

These findings indicate that we believe that students in Ghana experience limited technology use in their chosen disciplines. Our findings seem to support earlier findings that educators find it difficult to integrate digital capabilities in context of subject disciplines or students lack the key digital competencies necessary to thrive in the digital society.

As such, the findings suggest that faculties should move beyond the passive use of digital technologies for teaching and learning to embed digital skills in their subject disciplines to enable learners to be active users of technologies. Universities, departments and faculties should be direct more effort at developing students’ digital capabilities in context of their chosen career to prepare students for the digital workplace. Digital activities should involve the use of technology beyond the mere searching for information and should include digital communication and collaboration, digital problem solving, production of digital artefacts other than Word or PowerPoint, like digital portfolios.

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LEARNING DESIGN PRINCIPLES TO SUPPORT COMMUNITIES OF PRACTICE IN A BLENDED LEARNING PROGRAMME

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ABSTRACT: Learning design principles of high-impact blended learning programmes in higher education institutions and the subsequent design decisions are not often offered for dissemination to a wider audience. This paper considers the case of a new short learning programme articulated to a NQF level 8 programme aimed at capacitating the education sector with a reach into each district in South Africa. The programme was designed over a period of 18 months and builds on previous professional development interventions with the same cohort. This bespoke offering is informed by the development of robust Communities of Practice (CoPs) to further afford sustainable change at school level. As such, the following four emerging learning design principles that underpin the design decisions in this programme are offered for interrogation: opportunity to model professional behaviour; develop social foundations from which to build the CoP; sustaining guided and self-regulated learning; and realignment and reinforcement of the course objectives. Some recommendations are included. Subsequent publications will further interrogate the efficacy of the design.

Keywords: Learning design principles; professional development; online and face-to-face learning spaces; learning design decisions; Communities of Practice

INTRODUCTION

This paper in itself is not a report of an intervention. It is a theoretically grounded design for a blended learning course, the short learning programme: Managing and Leading with Digital Technologies. The paper begins by showing links between learning design and Communities of Practice (CoPs). The case examined in this paper is a blended learning programme for professional development of managers of teacher centres where the aim is to support teachers in schools in the use of appropriate technologies for teaching and learning. The focus of the paper is to present four key design principles that informed the design of the blended course. The reason for focusing on the design rather than having an emphasis on the findings is that the role of design is often underplayed in academic reporting. In this respect, consideration is given particularly to the design principles that underpin the establishment of vibrant Communities of Practice in the programme.

LEARNING DESIGN MEETS COMMUNITIES OF PRACTICE

Conole (2012) described learning design as a process whereby teachers or designers plan learning instances to reach desired learning outcomes whilst matching specific pedagogical approaches with the most suitable technological tools and services available in a specific educational space. In a collaborative learning space, these decisions are informed by the knowledge, skills and attitudes of participants as well as the reasons for cooperating. As such, CoPs have become a popular mechanism to scaffold professional development among practitioners. Both the concept of CoPs and the enactment thereof create value when used as a means to explore, contest and refine ideas both collectively and individually (Blackmore, Foster, Collins, & Ison, 2017). Providing meaningful and authentic learning experiences explicitly connects learning design principles to the establishment and development of such robust CoPs. These learning design principles pertain not only to the process of growing and sustaining the particular CoP, but also to the range of activities and associated technology choices to support the lifecycle of the CoP (Cambridge, Kaplan, & Suter, 2005).

In terms of professional development, the advantage of participating in a CoP, apart from peer-modeling by which participants share resources through curation, refine their beliefs and ideas, members also collectively make joint decisions regarding the scope and relevance of their community. The value of a CoP in learning design is that multiple perspectives and experience can inform the final design decisions. In addition, if participants in a CoP derive value from the shared experience, they are more likely to adopt and advocate models of teaching and learning strategies in which discussion and sharing of ideas are central.

An important aspect of this particular programme was that it would be designed and offered in a blended learning mode. Blended learning can also be described as hybrid learning, flexible leaning or even mixed-mode learning; it accommodates synchronous and asynchronous communication as well as formal and informal forms of learning. In essence, blended learning addresses the need to provide a variety of coherent measures at the pedagogical, organizational and technical levels to assist students to achieve intended learning outcomes. The blend will vary depending on the nature of the discipline; profile and context of the students; type of learning material; level of interaction required; fidelity; and technology solutions available to complement the face-to-face teaching and learning environment. The main tenet of blended learning is to fully exploit the affordances of learning technologies to accommodate and allow different ways for students to engage with curriculum and faculty whilst demonstrating their learnings. With the expansion of blended learning offerings in higher education, there is a growing interest in how CoPs can further support and sustain learning beyond course boundaries (Halverson, Graham, Spring, Drysdale, & Henrie, 2014).

Higher education institutions, making the transition from the more traditional face-to-face mode of delivery to include more elements of open and distance learning, find it a major challenge when confronted with the myriad of choices in terms of pedagogy, technology and discipline expectations. In traditional face-to-face environments, educators tend to focus more on traditional teaching patterns, such as the 'teach, practice, apply' mode (Toetenel & Rienties, 2016). In blended and online learning approaches, more consideration is given to create technology mediated learning experiences. Alammery, Sheard and Carbone (2014, p. 443) identified three distinct processes when designing blended learning courses based on the level of changes required in existing offerings:

- (1) Low-impact blend: adding extra activities to an existing course
- (2) Medium-impact blend: replacing activities in an existing course
- (3) High-impact blend: building the blended course from scratch

In the low-impact approach, most course designers simply add technology-mediated instances to their existing course materials without eliminating existing activities as their choices are limited due to their inexperience and knowledge about appropriate technologies and their associated pedagogical affordances. In the medium-impact blend, courses are redesigned to replace face-to-face with online activities. Designers make a concerted effort to re-conceptualize learning activities and target key areas that might work better in the online medium. This approach requires long-term planning and is iterative in nature with constant refining of the offering. The high-impact approach, which is the most difficult to apply, requires significant investment of seasoned designers with high levels of technological and pedagogical confidence and can be described as a full redesign, total redesign, or radical change. Such a radical approach is most suitable for new course offerings or courses that require revisiting course objectives with a stronger focus on the participants' needs. The lead time for development is up to three times longer than for courses developed in the traditional format.

BLENDED LEARNING COURSE CONTEXT

Goal Four of the sustainable Development Goals commits the international community to “ensure inclusive and quality education for all and promote lifelong learning.” This is echoed in Goal 20 of the Department of Education’s (DBE) Action Plan to 2019. It accentuates “increase access amongst learners to a wide range of media, including computers, to enrich their education.” As such, appropriate use of Information and Communication Technologies (ICTs) in teaching and learning in the classroom becomes paramount to develop habits of continued learning beyond formal schooling. The White Paper on e-Education (2004) outlined the elements of transformed learning and teaching through ICTs. It was supported by the publication of Guidelines for Teacher Training and Professional Development in ICT (2007), which provided principles for teacher professional development in ICTs and teacher competencies within a developmental framework. Goal 16 of the Department of Basic Education (DBE) Action Plan to 2019, further commits the Department and its partners, to improve the professionalism, teaching skills, subject knowledge and computer literacy of teachers throughout their careers. Consistent with the DBE Action Plan to 2019, the Integrated Strategic Planning Framework for Teacher Education and Development (ISPFTED) commits all partners to invest in digital technologies to support the delivery of the strategy.

The purpose of this particular short learning programme (SLP) was to enable education officials in the DBE and Provincial Education Departments (PEDs) to effectively harness the potential of digital technologies in support of their management and leadership roles. Disparate qualifications of existing Teacher Centre Managers ranging from technical, managerial to educational qualifications resulted in differing approaches to problem solving. The distinct lack of coherence between past training instances with little articulation to formal accredited training programmes for progression also emerged as a stumbling block to sustained professional development. As such, a dedicated learning programme that integrates self-management with appropriate leadership and management tools in ways that harnesses the potential of ICTs was designed, developed and delivered as a continuing professional development opportunity.

The design purposively created opportunities for participants to interact with one another and with faculty members within a CoP. The design served to accommodate both a geographically dispersed participant cohort and individuals with challenging work schedules. Learning design principles supporting the development of a robust CoP is central to the authenticity of the actual course. The programme aimed to deliver a contextually relevant course to enable education officials to lead and manage change and complexity by harnessing the potential of digital technologies. Also, it aimed to provide education officials with a university-accredited qualification that can contribute towards their individual lifelong learning pathway and continued professional development.

According to the Alammery et al., (2014), the course designed to capacitate educational officials, can be considered as a high-impact blend. The new offering allowed for flexibility in terms of the choice of pedagogy employed as well as tools and services selected in the delivery of the programme because of the radical change when it is compared to traditional offerings.

BLENDED LEARNING PROGRAMME (CONTINUING PROFESSIONAL DEVELOPMENT: ICT CENTRE MANAGERS)

This SLP targeted 166 DBE Managers of District Teacher Development Centres (DTDCs) and Provincial Teacher Development Institutes (PDTIs), which are collectively called Teacher Centres, and eLearning Specialist Trainers who serve on the DBE’s National Core ICT Training Team (NCITT) in all Provincial Education Departments (PEDs). These Teacher Centre Managers and eLearning specialists are embedded within each district in South Africa and have a mandate to capacitate the professional development of teachers in providing appropriate and contextual in-service training opportunities

and to implement the DBE's Action Plan to 2019 in a response to the priorities, targets and programmes articulated in the National Development Plan, 2030.

Participants who complete this accredited SLP will strengthen the education sector in South Africa, in particular the DBE and PEDs, by contributing towards effective leadership and management of education in the design and implementation of teacher development initiatives in each district of South Africa. The practical ICT skills they acquire during this course and the deepening of their theoretical understanding will allow them to identify and address various tensions in their own ICT work activity systems. They can also be equipped to establish vibrant subject-specific Professional Learning Communities (PLCs) in their districts. These DBE-mandated PLCs for teachers supported and mediated with various ICT tools and services will further build capacity in each school. Furthermore, they can expand their own pedagogical repertoire, modelling appropriate and subject-specific ICT use in the various teachers training instances they are required to host in their districts.

This particular SLP was purposefully designed to fully exploit the affordances of digital technologies in a blended learning space supported by the availability of tutors on a 1-10 ratio to address concerns of high attrition rates endemic to online learning. The programme was delivered over a period of eight months combining an initial four-day face-to-face component in July of 2016 followed by the online phase.

The overall programme design is immersed in principles of authentic learning (Herrington & Reeves, 2017) with a strong emphasis on:

- Managing and leading change through self-management
- Policy and institutional contexts with reference to teacher development and digital technologies
- Driving optimal use of education resources and digital technologies
- Innovative digital tools for collaboration and knowledge creation
- Making data-driven decisions as educational intervention
- Competencies and attitudes necessary for lifelong learning.

There are a number of desired learning outcomes for the SLP of which a COP is one of them. This overall aim is to get a sustainable model for teacher support for the use of technology for teaching and learning. Therefore, we began with the ICT managers as change agents within each of their districts. Their establishment of a COP is crucial to moving/ working with teachers in their regions. Once they have had a lived experience and can acknowledge the benefits of being a member of an active COP, they are more likely to establish similar COPs with the teachers in their districts. Teachers in turn can then develop their own Professional Learning Communities (PLCs) in their own learning areas.

Whereas some of these centres are located in very poor under-resourced areas, others are situated in more established areas with more access to resources that result in a robust knowledge exchange amongst participants with the associated transference of ICT and leadership skills. As such, forming CoPs across socio-economic boundaries amongst district officials and teacher centre managers ensures a rich exchange of ideas that can result in appropriate and contextual measures to be implemented in their respective communities. Furthermore, the strategic selection of participants ensures that a larger number of officials are skilled; it ensures a better possibility for sustainability and implementation of skills learnt. In turn, these skilled officials that can use their centres to more directly serve the needs of their particular education communities. In addition, due to the under-representation of women in the specific domain of ICT in Education, a conscious effort was made in the development of resource materials to promote positive role models in the selection of relevant cases.

Evaluation data collected during this course consisted of a variety of instruments, including: an entry-level survey, exit-level survey, Community of Inquiry survey, participant observation, digital artefacts, activity logs, tutor logs, and guided reflections. Detailed analysis of this data will be reported in future publications. As indicated earlier, the focus of this paper is in the explicit articulation of learning design principles in relation to CoP as manifested in this blended learning programme.

COMMUNITIES OF PRACTICE

The applied learning design principles pertaining to the development of CoPs within the scope of this programme, their theoretical underpinnings and enactment thereof, are presented in Figure 1:

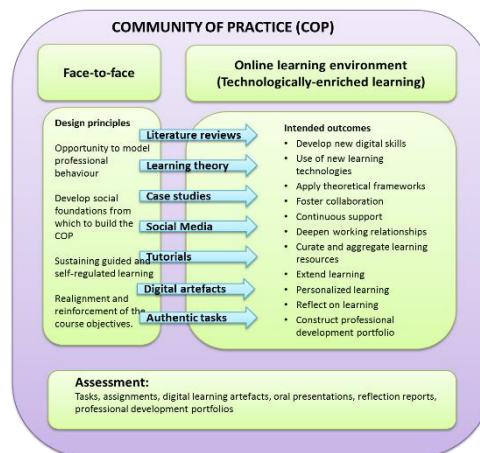


Figure 1: COP design principles

The structure of the SLP is visually presented in Figure 1, and recognizes the importance of CoPs in the successful delivery of a blended learning programme. In particular, it is important to avoid a top-down transmissive model where ICT managers have power and use that power and authority to dominate what happens in schools. What we want is for them to enable and empower teachers to make their own decisions about what will work best in their classrooms. Engagement in a CoP cultivates a sense of belonging based on a social and constructivist orientation to learning. The face-to-face environment is designed to have opportunities for managers to get to know each other on a personal level; it allows them to build strong social foundations that will sustain their self-directed learning and online collaboration. Face-to-face encounters are usually characterized by high energy levels that motivate, inspire confidence and reinforce/ nurture professional behaviour. Managers are exposed to exemplary pedagogical practice as modelled by their facilitators who enact practices underpinned by educational theory.

Face-to-face encounters allow for the realignment and reinforcement of the course objectives. The online environment allows for students to further foster and build their CoPs through collaboration and knowledge sharing; thus, they experience technology-enriched learning. This will necessitate the development of a digital skills set that will grow as they become more confident in their ability to develop, curate and aggregate information. Their learning becomes enriched and is extended beyond the environment of their own context. Usually members of a CoP can assist one another through teamwork in the completion of their tasks. Support is provided by a members of the CoP with a variety of sources as they continue to learn with and from one another.

DISCUSSION OF LEARNING DESIGN PRINCIPLES

The design principles informing the face-to-face component derived from literature and enacted in online component comprise of the following: opportunity to model professional behaviour; develop

social foundations from which to build the CoP; sustaining guided and self-regulated learning; and realignment and reinforcement of the course objectives.

Opportunity to model Professional Behaviour

Participants were expected to use the tools of their trade which included the connected digital devices supplied to them by their various PEDs in order to complete the SLP successfully. Assignments were designed for participants to demonstrate proficiency substantiated with evidence of implementation. Practical complexity and levels of theorizing and abstraction increased as participants progressed through the programme. Eventual success was dependent on demonstrating technical, academic, contextual and practical competencies. The teaching and learning strategy of the programme is a departure from information delivery. It does not view learning as information consumption, and assessment is not viewed as information replication. The programme did not foster rote learning, rather, it fostered deep and meaningful learning — learning that is “rich with connection-making” needed for “insight and for the lively and flexible use of knowledge” (Wirth & Perkins, 2008). When deep learning occurs, students are empowered to transform the communities they serve (BOEI ET AL., 2015; LUNENBERG, DENGERINK, & KORTHAGEN, 2014)

Develop Social Foundations from which to Build the COP

Professional development needs to be an authentic experience for the managers in terms of what they want teachers in schools to achieve. Cultivating a social presence including the degree of awareness of others is positively linked to learning outcomes (Akcaoglu & Lee, 2016). Social affordances in the form of increased online interactions promote comfort and emotional connections between students or participants. One of the key aims of this SLP is that ICT centre managers and the teachers in their districts form social connections with each other in the form of functioning CoPs. As a result, they first need to have an authentic immersive type experience of CoP before they can facilitate these types of communities. The use of ICTs in a changing educational landscape is explored from eco-systemic perspectives. It leads to understanding the dynamic contexts of education that can enable students to make informed decisions about ICT use in education at the policy level, contextualized for the environments in which they work. In this way, student learning becomes meaningful and will have relevance and influence in the shaping of a better future for the communities which they serve.

Sustaining Guided and Self-Regulated Learning

Nilson (2013) considered self-regulated learning as a multi-dimensional and multi-stage process requiring conscious planning, monitoring and evaluations of one’s learning in order to advance lifelong learning skills. This SLP instilled the attitudes, values and competencies necessary for lifelong learning, including dimensions of self-regulated learning, of metacognition and emotional and motivational control. The strong theoretical foundations of the programme can not only advance the scholarship of teaching and learning, and research but also, through a combination of guided and self-regulated activities, create opportunities to reflect on learning. Students will be empowered to practice quality ICT-mediated teaching and learning as they collaboratively learn from and with each other. As a result of increased levels of self-regulation, students become agents of transformation and innovation.

Realignment and Reinforcement of the Course Objectives

The teaching and learning strategy is further premised on authentic learning principles. This means that students will encounter learning tasks that have real-life meaning, are ill-defined, are cross-disciplinary, rely on peer collaboration, produce polished products that have value in their own right, and where multiple outcomes are possible (Herrington & Reeves, 2017). It also provides for learning about emerging learning technologies as they become available, and students can engage with these tools and apply learnings in the authentic contexts in which they practice. Learning tasks meet

the criteria for authentic learning, since there is a strong emphasis on the development of ICT skills, specifically skills in the use of a variety of online ICT tools in contextual settings. Students are required to develop authentic learning artefacts that are polished products that are immediately useable.

The learning design principles were enacted in the units as captured in the assessment criteria as presented in Table 1:

Table 1: Content areas mapped to units, topics, outcomes and assessment criteria

CONTENT AREAS			
Unit	Topic	Outcomes	Assessment criteria
1	Leadership in ICT – driving sustainable change	Display active leadership in education communities and professional development groups as agents of change	Develop and collect evidence of engaging with the wider education community in conceptualizing and providing instances of continuous professional development as needed in the districts.
2	Learning Theories	Engaging with learning theories around adult learning (andragogy)	Andragogy and associated with 21 st century skills
3	Appropriate ICT tools and services for lifelong learning	Select and apply appropriate ICT solutions to various educational scenarios	Create a variety of multimedia in the form of various digital learning artefacts and display competence in the planning and management of educational /instructional media facilities and programmes.
4	Communities of Practice of theoretical framework as	The Theory of Communities of Practice Engaging with ICT innovation in Education	Communities of Practice as a mechanism to drive change in teacher professional development Learning from research
5	Policy and Practice interchange	Understanding the relevant policies, guidelines and plans and how it impacts my working environment Exhibit knowledge and understanding of complexity of implementing ICT solutions in Education	Reflecting on key policy issues highlighted during SWOT analysis in closing the gaps To conceptualize and develop an articulate reflective report: Leading with technology in my district: A contextual implementation

The selected topics for the programme are relevant in an emerging and evolving educational landscape. They are sufficiently agile to dynamically influence and enable better learning outcomes for the participants in the programme. The programme is sufficiently responsive to the needs of the developed and developing contexts, to be influential in shaping the future in both contexts. It makes provision for an exploration of a range of pedagogies that are appropriate for the diversity of contexts in which ICT is used for educational purposes.

RECOMMENDATIONS FOR FURTHER ACTION

Firstly, we find that there is a pressing need for a deeper articulation of qualifications available in the education space. The attraction of completing this particular NQF level 8 SLP resides in the potential to progress to the full qualification: Postgraduate Diploma in Education — ICT innovation in Education.

Secondly, the blended mode of delivery played a key part in the success of the programme. Not only did it ensure increased access to a quality programme outside of individual provinces, but also provided a sense of purpose in learning more about learning with digital technologies. Being forced to interact online to complete this programme also ensured the strengthening of individual digital skills as well as improving confidence in using digital technologies for learning. Participants can now assertively model future teacher professional development instances in their own provinces, having had the advantage of a personal lived experience in completing a blended learning course. Going forward, they will receive some assistance in considering aspects of learning design for digital learning when delivering teacher professional development workshops in their own provinces and districts. The next SLP in this series will be designed to focus fully on this aspect.

Thirdly, regarding the importance of supporting emerging CoPs, the timing of the face-to-face phases was critical in allowing students not only to meet their facilitators and tutors, but also for them to get to know each other across provincial boundaries. Where existing provinces did not have well-established CoPs, students organized themselves by forming working groups that later evolved into strong CoPs. Within these CoPs, they were not only personally accountable for their progress but also to each other. A strong camaraderie seemed to develop naturally and grow within provinces. More thought needs to go into how to harness and support these CoPs to gain further traction in districts and provinces.

Fourthly, the level of visible support from project partners further strengthened their resolve to complete the programme. Each of the partners provided visible and tangible support for the candidates, thus, underscoring their value within the programme as well as the critical role they play in the implementation of educational policy. The thrill of meeting the Minister of Basic Education and living up to her challenge of a 100% pass rate provided additional incentive not only to complete, but to also excel in the programme.

Fifthly, the level of support, provided in the form of online tutors and readily available facilitators, contributed greatly to the high throughput rate. Additional lines of communication in the form of mobile chat groups were established where participants felt safe to make enquiries or request additional support. The amount of digital scaffolding required from tutors and facilitators was not anticipated, nevertheless, it was provided in the form of supporting videos and tutorials in line with the objective of not leaving anyone behind on this journey. More can be done in future by anticipating and addressing support needs early in the course that may arise due to differing level of familiarity with educational theory as well as differing competencies in using learning technologies.

On completion of this innovative educational offering, institutional leaders have the potential to foster change by embracing new models of professional development by recognizing and encouraging collaborations that seek to advance the practice of learning across geographical boundaries.

In general, the overall design was validated and is presented to the ISTE community to engage with. Thus, the theoretical framework covered a range of learning designs appropriate to develop and grow robust communities of practice.

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THE PHYSICAL AND PSYCHOLOGICAL IMPACT OF INFORMATION TECHNOLOGY USE ON UNIVERSITY STUDENTS

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ABSTRACT: The use of technology in education has vastly improved the efficiency of students' ability to learn and to interact in the classroom setup. However, it cannot be denied that technology has certainly caused many negative concerns as well. Examples include smartphone addiction, bullying, cybercrime, and physical side effects, such as carpal tunnel syndrome and back problems. This paper reports on a study done to assess the impact of information technology on university students' physical well-being and psychological health. In addition, an intervention activity was planned in order to make the students more mindful about their interaction with technology. An empirical study was done to investigate the impact of information technology on university students. A primary outcome of the study was the increase in awareness of the negative effects that the use of information technology may have on students, ultimately empowering them to positively adapt their behavioral patterns to act in a more secure way.

Keywords: Technostress; ergonomics; physical and psychological implications; university students

INTRODUCTION

Information security resides on many levels, such as social and administrative levels, with technical measures often being perceived as the most well-known level. However, humans can be regarded as the weakest link and therefore raising information security awareness is needed (Schneier, 2011). Many people experience negative emotions regarding their interactions with computers (Shu et al., 2011). A study by D'Arcy, et al. (2014) indicates that a person spends an average of 28 percent of his/her workday on IT-related interruptions, which can have severe psychological effects on the human brain. Humanity is under pressure to keep abreast of the new technologies and to learn the necessary skills to stay competitive. Universities are institutions that lead and are changed by technology, at such a level that employees and students need to adapt and develop their activities and methods. The inability to adapt to new technologies or to deal with it in a healthy manner is called technostress (Yin et al., 2014). Technostress can place physical and psychological stress on a person in the form of high blood pressure, heart failure, and musculoskeletal disturbance (Lee et al., 2014).

Implications of psychological effects on a person may include the following: the inability to concentrate in a class as a result of mobile phone usage, feeling threatened by people who own newer technological devices, and spending time on a mobile phone rather than spending it with people (Lee et al., 2014). Another aspect mentioned by D'Arcy et al. (2014) is the addiction to IT-related artifacts. In some cases, users can develop an abnormal dependency that can lead to the cancellation of important activities in order to spend time with IT devices. Examples include spending time on social networks, online video games, and online gambling.

The physical effect that information technology usage may have on an individual is mainly related to ergonomics. Olaniyi et al. (2014) define ergonomics as the process of designing and rearranging a workplace, product, or system to accommodate the user. Ergonomic risks, such as a poorly designed

workplace or repetitive movements can contribute to cumulative trauma disorders affecting a person's hands, joints, lower back, etc. (Olaniyi et al., 2014).

The purpose of this paper is to report on a project that was undertaken to assess the impact of information technology on first-year university students' physical well-being and psychological health, including information security issues. The purpose is additionally to show how an intervention action in the form of an information session and educational efforts may address the awareness shortcomings for these students.

BACKGROUND

Academic research focuses increasingly on the negative impact of IT usage according to D'Arcy et al. (2014). In the case of smartphones, the negative aspects are not mainly concerning the functionality of the device itself, but rather the way it is used. Users form such a powerful connection with their smartphones that the idea to function without these devices is unthinkable (Aljomaa et al., 2016). Often the term used for these negative impacts is the dark side of technology. Students' enthusiasm with technology may result in negligence in other important aspects of their real lives, such as their academic commitments, family life, etc. (Aljomaa et al., 2016). D'Arcy et al. (2014) support this statement by discussing the overload of information. Students stumble from distinguishing between valid and invalid information. This level of obsession is identified by Aljomaa et al. (2016) as an addiction, and can be categorized as a psychological effect. Clearly, there are advantages and disadvantages when using information technology.

Physical impact of IT use

The physical effect that IT use has on an individual's body can be linked primarily to technostress and ergonomics. Olaniyi et al. (2014) refer to technostress as a modern disease that arises from a user's inability to handle new technology in a healthy manner. Technostress refers to the physical and psychological pressures that are placed on an individual by using information technology. According to Mahalakshmi and Sornam (2011), there are two forms of technostress: the physical, as well as the psychological types. Symptoms that indicate that a person is experiencing technostress include the inability to concentrate on a single issue, a quick temper, and a feeling of being out of control (Olaniyi et al., 2014). Examples of situations that give rise to technostress are: users fail to remember all the different passwords for multiple systems, hardware or software systems that fail unexpectedly, the amount of spam that users receive; slow internet connections and the lack of human or social interaction when spending time on digital devices. Mahalakshmi and Sornam (2011) state that there has been a focus on technostress since 1986. They indicated how correct ergonomics improved the physical side effects, such as eye strain, musculoskeletal problems, headaches, muscle disorders and sleep disturbances. According to Olaniyi et al. (2014), ergonomics is the process of manipulating the work environment to suit the user, instead of adapting the user to the work environment. It includes also rearranging working conditions to ensure optimal use (Mahalakshmi and Sornam, 2011). General steps that can be taken to create an ergonomically-friendly work environment include: Adequate floor space for comfortable movement, a safe working environment e.g. no loose wires and for personal health, users must regularly take a break for eye muscles relaxing and readjusting body muscles. Badly designed workstations, long periods of keyboard use accompanied by frequent and uncomfortable body movements are examples of ergonomic hazards that can lead to increased trauma disorders (California Department of Industrial Relations, 2005). In order to avoid the negative impact of IT use, there are overall goals that must be achieved to realize a well-designed ergonomic workplace. These goals can be divided into three categories, namely the user's position, how he/she uses the keyboard, and the interaction with the computer's screen (California Department of Industrial Relations, 2005).

Psychological impact of IT use

Some people use their mobile phones excessively and it can be stated that they are addicted to the use of their smartphones and lead a life of isolation (Aljomaa et al., 2016). Young (1998) published an article in 1998 entitled "Internet addiction: The emergence of a new clinical disorder", and Aljomaa et al. (2016) assert that smartphone addiction will have an even greater impact than internet addiction. Individuals who struggle to control their smartphone usage may experience social, psychological, and health problems as a result (Aljomaa et al., 2016). D'Arcy et al. (2014) identify five risk factors that can create stress on a psychological level: techno overload, techno invasion, techno complexity, techno uncertainty, techno disruption. Research on the effect of smartphone addiction on student behavior indicates a correlation between smartphone addiction and amongst others depression, anxiety, and low academic performance (Aljomaa et al., 2016). Individuals who suffer from technology addiction tend to distance themselves from work, studies and social life. Consequences of technostress on a psychological level are as follows: The user's energy levels are drained, information overload and job insecurity is being experienced, jealousy arises between employees with different levels of computer skills, loss of motivation and users neglect their social life. To prevent psychological consequences of IT use, there are actions that can be taken to mitigate the effects of the risk factors. Technical support can be provided to users in the form of training, where users can learn technical skills at their own pace. Additionally, users can be encouraged to experiment with IT functionalities, hoping they will enjoy the experience in order to reduce their stress levels (D'Arcy et al., 2014). Users can be made more aware of the dark side of technology with information in formal and informal sessions to gain an understanding of the negative impact of the use of IT.

RESEARCH METHODOLOGY

Literature was reviewed to obtain background particulars on the topic. Surveys (observations and questionnaires) were used as the data collection strategy for the empirical study. The observations were primarily used to identify the physical impact that IT use has on university students. Electronic questionnaires were used to identify mainly the psychological effects on students. The implementation of the data collection methods was spread over three occasions. The first phase of the investigation consisted of two observations. The first observation took place in two separate classes to document the students' ergonomic levels with the aid of an observation form. After the results had been recorded and documented, an information session was held in one of the classes. The students were made aware of the ergonomic correct way in which a computer is to be used and the physical way of sitting and using the keyboard and screen. The second observation opportunity took place once again in both classes to document the students' ergonomic levels. The aim was to observe the change, if any, in ergonomic interaction within these two groups. Again fifty students in each of the 2 classes were observed a second time. The second phase of the investigation was to use questionnaires that assess the psychological well-being of students and the impact that information technology use has on the students. The online questionnaire was completed by 168 students. The collected data was processed statistically to describe the general trends and distribution (Oates, 2006).

RESULTS AND DISCUSSION

The observations where the students' ergonomic levels were evaluated took place in two separate first-year classes of the same introductory computing module (50 observations each). A checklist of evaluation criteria was compiled by using the information obtained during the literature study. Each student received a score out of three for each criterion, where three is the highest mark for achieving the criteria. A total of eight questions had been identified, which served as the criteria for the observation list:

- 1) Are both the students' feet flat on the ground?
- 2) Is there a small gap, about five to ten centimeters, between the front of the seat and the back of the student's legs?
- 3) Does the student's back fit against the back of the chair?
- 4) Are all computer components within easy reach of the student?
- 5) Are the student's arms relaxed and close to his/her body?
- 6) Are the student's elbows bent at ninety degrees, or slightly more?
- 7) Are the student's joints straight? 8) Is the highest point of the monitor equal to the student's horizontal eye level?

A total of four observation sessions were made in two separate classes over a period of a few weeks. 50 students were observed in each class. Both classes were observed in the first week in the initial stage. Thereafter the second class participated in an information session between the lecturer and research student. The purpose of the information session was to make the students aware of the dangers that may occur when using information technology. An information sheet was given to each student with tips to interact in an ergonomically correct way at a workstation. The two class groups were observed again within three weeks in order to evaluate the effects of the briefing session given to the one class. The collected data consisted of the scores awarded to each student in respect of the eight identified criteria. This data has been processed quantitatively in order to ascertain how the students interacted with the computer equipment and what the effect of the information session was – if any. Figure 1 indicates a summary of the four observations and the average ergonomic performance of the participants in the two classes. From Class 2 results, it can be seen that providing an awareness session empowers students to improve their habits and ergonomic interaction with the computers. Before the information session, they had an ergonomic performance of 62%, which improved to 73 after providing an information session. An improvement of 11% indicates a positive result.

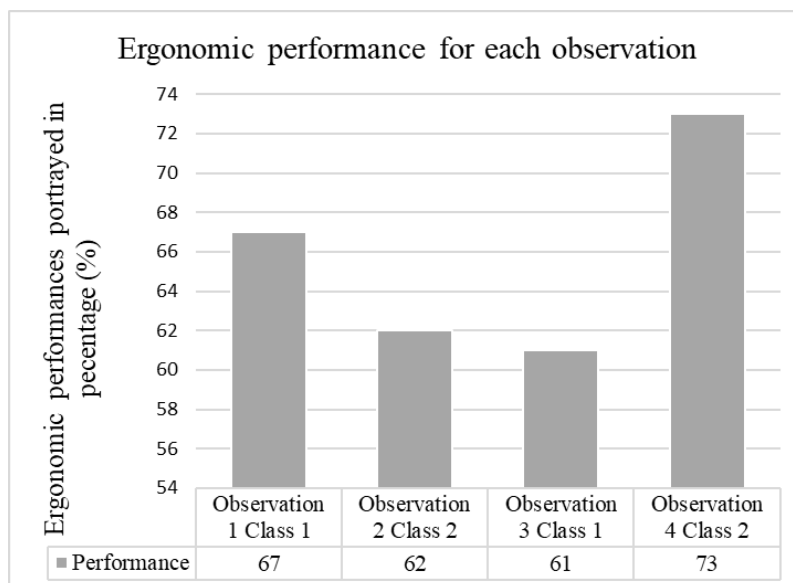


Figure 1: Ergonomic performance per observation

The two least compliant criteria have a performance level of 57%. They are: the feet that have to be kept flat on the ground, and the arms that have to be kept relaxed and close to the body. From the observations it was noted that students tend to cross their legs at their knees or extend their legs straight. Regarding the relaxed arms that should be kept close to the body, the computer room's chairs are slightly too low to hold their arms close to their bodies. The highest achievement level of 74% was where the students' lower back fits comfortably in the backrest of the chair. With this

insight a proposal can be made to the particular university to place adjustable chairs in all computer rooms. Short students are sitting too low at the table to be ergonomically correct; therefore, their arms and their eye levels are incorrectly positioned. With this collected data and interpretation, the ergonomic aspects of IT use can be addressed.

Data regarding the physical and psychological well-being of university students were collected using an electronic questionnaire. The questionnaire consisted of the following categories: Biographical information, the use of smart devices, the use of the Internet, the playing of games and ergonomics.

The gender distribution of the participating students is 81.5% male and 18.5% female. The majority of the participating students used their smartphones during class for non-academic purposes, and play games on their smartphones. Smartphones have the highest frequency of use of IT devices, 76.2% of users use them all the time.

Table 1: Tabulated Results of the Questionnaire

Question	Frequency N(%)		Scale from 1 to 4 Strongly disagree – Strongly agree	
	Agree (3,4)	Do not agree (1,2)	Average	Std deviation
I regularly use a smartphone during classes for non-academic purposes	101(60.1)	67(39.9)	2.62	0.749
Smart devices in my bedroom often have a negative effect on the quality of sleep I get	62(36.9)	106(63.1)	2.19	0.947
I regularly send electronic messages to individuals who are in the same building as I am	32(19)	136(81)	1.63	0.872
I regularly listen to music, or watch a movie while doing my homework	93(55.4)	75(44.6)	2.57	0.995
I regularly experience online harassment	13(7.7)	155(92.3)	1.54	0.673
I regularly watch adult content on the internet	34(20.2)	134(79.8)	1.8	0.884
I often lose hours of sleep due to playing digital games	40(26.8)	109(73.2)	2.05	0.899
I rather play games than pursue new hobbies	66(44.3)	83(55.7)	2.29	0.888
I often experience intense emotions while playing games	59(39.6)	90(60.4)	2.23	0.982
I wish that I could be more like the character in my game	57(38.3)	92(61.7)	2.08	1.017
I regularly insult other players if they make mistakes	38(25.5)	111(74.5)	1.85	0.925
I fear a life without digital games	39(26.2)	110(73.8)	1.87	1.038
I often experience pain or discomfort in my lower back	72(42.9)	96(57.1)	2.25	1.013
I often experience pain or discomfort in my upper back	45(26.8)	123(73.2)	1.94	0.94
I often experience pain or discomfort in my neck	82(48.8)	86(51.2)	2.32	0.974
I often experience pain or discomfort in my arms and shoulders	42(25)	126(75)	1.93	0.923
I often experience pain or discomfort in my joints and hands	45(26.8)	123(73.2)	1.96	0.956
I often experience pain or discomfort in my eyes	67(39.9)	101(60.1)	2.21	1.002

Table 1 presents some results from the questionnaire. From this sample, 52% of students experience negative emotional responses when someone or something interrupts their game playing. From the participants there are 46% of students who play games rather than pursue other hobbies. This is disturbing as the social life of humans can be negatively affected by using/misusing IT. From this sample, 43% of the students experience overwhelming feelings during games. This result was also found in the work of Mahalakshmi and Sornam (2011) and Aljomaa et al. (2016) where people showed short temperedness and conflict with other people when spending a great deal of time with information technology. It can be seen that students try to multitask such as doing academic work and watching movies at the same time – this may have a negative effect on their academic performance. Looking at the physical issues, it can be observed in Table 1 that the participants do experience discomfort regarding their backs, eyes, etc. There were even a few students (13) reporting that they have experienced online harassment.

From the interpretations from the survey it is seen that information technology has in certain areas definitely a negative impact on the students. This is congruent with literature in this regard. For instance – the students' obsession with their smartphones (60.1% using it for non academic reasons during classes) can affect their attentiveness thereby influencing their performance and completion of tasks (Aljomaa et al., 2016) and influence their social behavior negatively.

CONCLUSIONS

The problem addressed in this study is the dark side of technology – the negative effects that IT use has on students' physical well-being and psychological health, as well as their awareness about the risks and dangers. An empirical study has been conducted to collect data in this regard, using observations and questionnaires. It was shown how an information session to raise awareness on the ergonomic correct use of computers improves the students' interaction with computers. Further data collection took place in the form of questionnaires. The study has identified and discussed the physical and some psychological effects that information technology use could have on a university student's well-being. The contribution of this study is that providing information to students (in an educational setup) regarding the effect of IT use empowers them to positively adapt their habits. Furthermore, it is also seen how feedback from this survey can be used by the university regarding the facilities provided to students so that they may interact with the computers in an ergonomically correct way (e.g. size and height of chairs in computer laboratories). Future work will be to investigate the best ways to educate students and other computer users regarding these matters. The data from these kinds of surveys will be used to enhance awareness programmes to further empower students on all levels to become aware of the negative impact of IT use in order to be healthier on a physical and psychological level. In doing so, the impact of technostress on students can be reduced.

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PRE-SERVICE TEACHERS' ACCEPTANCE AND USE OF FORMATIVE FEEDBACK IN AN ONLINE UNDERGRADUATE MODULE

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ABSTRACT: Many institutions of higher learning have adopted online learning but the high failure rate in MOOCs exposed the need to provide formative assessment feedback to enhance learning. In this study factors that influence the acceptance and use of feedback by pre-service teachers in an online module have been explored through a research survey by gathering empirical evidence based on the modified Unified Theory of Acceptance and the Use of Technology (UTAUT2). Survey data collected from 214 respondents was examined using factorial analysis to validate the questionnaire items and regression analysis to build a predictive model. Regression analyses showed that hedonic motivation, perceived relevance, facilitating conditions, perceived importance and habit account for 55.6% of the variance explained in behavioral intentions in the acceptance and use of formative feedback in an online course.

Keywords: Formative assessment feedback; hedonic motivation; pre-service teachers

INTRODUCTION

Massive Open Online Courses MOOCs exploded on the international educational platform in 2012 and held much promise in the online education space (Daniel, 2012). Although thousands of people enrolled for MOOC courses, the completion rates have been appalling (Khalil & Ebner, 2014). Most recently, traditional universities have started offering online degree courses or on-campus online courses. However, these courses have also been characterized with high dropout rates (Moore & Greenland, 2017). For example, attrition rates exceeding 20% have been observed across Australian open-access online degree units (Greenland & Moore, 2014). In MOOCs, the inability of automated systems to capture “semantic meaning of answers” for open-ended questions limit the feedback that the students receive from lecturers/facilitators especially in extended MOOCs which are commonly known as xMOOCs (Kulkarni, Wei, Le, Chia, Papadopoulos, Cheng, & Klemmer, 2015). In addition, high enrolment rates in MOOCs resulted in lecturers/instructors providing generic feedback directed at all participants rather than individuals, and sometimes not offered at all, thereby depriving students of much valued personal feedback (Bates, 2014). In short, most of these online courses lack personalized formative assessment feedback. In a recent study of pre-service teachers' understanding of learning design in MOOCs, participants found the generic type of feedback directed to all participants to be frustrating (Goto, Batchelor, & Lautenbach, 2015). Although peer and self-assessments can be used as alternatives in the provision of formative assessment feedback in MOOCs or online environments, they have been reported to have mixed results in their validity (Mostert & Snowball, 2013).

Formative assessments or “assessment for learning” are assessments that are used to evaluate students' activities where the evidence from these activities is used to modify teaching and learning so as to meet the students' needs (Baleni, 2015; William, 2014; Joint Information Systems Committee, 2010). Formative assessment feedback is the evidence generated from “assessment for learning” or formative assessments that is used by both lecturers and students to improve the quality of learning (Black, Buoncristiani, & William, 2014; Gikandi, Morrow, & Davis 2011). Formative assessment feedback is widely recognized as one of the most powerful influences on student learning (Hattie, Gan, & Brooks, 2016; Hattie, 2013; Hattie & Yates, 2013; Shute, 2008). Formative

assessment feedback can be provided by a lecturer, peer or self, regarding aspects of one's performance or understanding (Johnson, Reisslein, & Reisslein, 2015; Hattie, 2009). The provision of formative feedback enables students to evaluate, monitor and regulate their own learning, however, this does not take place in all contexts and not for all students can reflect (Evans, 2013). In this study, students engaged in online learning using authentic tasks to better contextualize their own learnings. Collins (1988, p. 2) as cited in Herrington (2007), defines Authentic learning as "notion of learning knowledge and skills in contexts that reflect the way the knowledge will be useful in real life." One of the most important features of Authentic learning pedagogy is that it creates opportunities of feeding forward formative feedback to future tasks (Mulliner & Tucker, 2017; Sambell, 2016; Hepplestone & Chikwa, 2014; Hattie & Timperley, 2007). Other aspects of Authentic learning include tasks that reflect real life activities, are completed over a sustained period of time, are complex, are ill-defined, have real-world problem solving facets, culminate in the creation of polished products, are seamlessly integrated with assessment, are interdisciplinary, allow for competing solutions, and provide opportunities to examine issues from a variety of perspectives (Herrington, 2007; Reeves, Herrington & Oliver, 2002).

AIMS OF THE PROJECT

The Department of Science and Technology Education in the Faculty of Education at the University of Johannesburg is transitioning one of its modules, Teaching Studies (TST20B3) in the Bachelor of Education degree) from traditional face-to-face learning into a fully online module with the inclusion of individualized formative assessment feedback. As such, there is an immediate need to learn more about providing quality feedback so that formative assessment feedback can be accepted and used by students to better achieve their learning outcomes especially in the online mode of delivery and not to replicate the formative assessment feedback mistakes as evident in MOOCs and other online courses.

The research question that emerged in this study was: What factors are important in pre-service teachers' decision in an undergraduate online module to accept and use formative assessment feedback during authentic tasks? The objective of the research was, therefore, to identify factors that influence the intention of 3rd year to pre-service teachers to use and accept formative feedback.

THEORETICAL FRAMEWORK

The modified Unified Theory of Acceptance and Use of Technology (UTAUT2) model by Venkatesh, Thong and Xu, (2012) was used to examine the factors that affect acceptance behavior and actual use of formative assessment feedback in this cohort of students in an undergraduate full online module. The UTAUT2 was derived from the UTAUT model which was created in 2003 by Venkatesh, Morris, Davis and Davis. The UTAUT2 model was created from 8 different models to include: Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM-TAM2), the Combined TAM and TPB model (C- TAM TPB), the Innovation Diffusion Theory (IDT), Social Cognitive Theory (SCT) and Motivational Model (MM) (Lu, Lin & Li, 2016; Liu et.al., 2015; Williams, Rana, & Dwivedi, 2015 ; Venkatesh, Thong & Xu, 2012; Venkatesh, Morris, Davis, & Davis, 2003).

In this study some of the original constructs of UTAUT2 (e.g. effort expectancy, performance expectancy, social influence, facilitating conditions that were hypothesized to be relevant to the acceptance and use of formative assessment feedback were retained while others Habit, Perceived Relevance, Behavioral Intention, Nature of Feedback Language, Perceived Importance, Hedonic Motivation, Self-Efficacy were incorporated. In the original UTAUT2 model, effort expectancy, performance expectancy, social influence, facilitating conditions were seen as the major influences

in the behavioral intention to use technology (Liu et al., 2015; Venkatesh, et al., 2003; Venkatesh, et al., 2012)

RESEARCH METHODOLOGY

This study was informed by a positivist philosophical underpinning. Accordingly, a quantitative study was undertaken where the measuring instrument was an online survey. A multi-racial cohort of 471 third year Bachelor of Education degree (BEd) pre-service teachers in the Teaching Studies (TST20B3) module took part in the study. The students involved in this study were being trained to teach in the Senior and Further Education and Teaching (FET) phase in a variety of learning areas at grade 10 to 12 level. Six experienced tutors and two lecturing staff provided feedback to the students. Of the 471 students, 214 students responded to the questionnaire giving a 45% response rate. Of the 214 students, 170 were Black, 18 White, 10 Indians, 8 Coloured, 2 Asians and 6 other than the ones mentioned. In all 137 students were females and 77 males. The majority of the students were in the 22-25 age group.

Data collection

214 students submitted their responses via an online survey tool that was presented to them in a Google form. The instrument was adapted from Venkatesh et al. (2012) and consisted of the following constructs and items respectively: Performance Expectancy (PE) (four items), Effort Expectancy (EE) (three items), Social Influence (SI) (four items), Habit (HBT) (three items), Perceived Relevance (PR) (three items), Behavioral Intention (BI) (three items), Nature of Feedback Language (NFL) (three items), Perceived Importance (PI) (six items), Hedonic Motivation (HM) (three items), Self-Efficacy (SE) (three items), and Facilitating Conditions (FC) (four items).

Respondents provided answers to each item on Likert-type agreement scales (7 point), starting from 1 (strongly disagree) to 7 (strongly agree). The instrument was validated in SPSS by calculating Cronbach’s Alpha and running a factor analysis to check for convergent and discriminant validity of the questionnaire items

Data analysis

Stepwise linear regression was used to determine the regression model and factor analysis was done to validate the questionnaire items

RESULTS AND DISCUSSION

Reliability

The reliability constant Cronbach’s Alpha, which is based on average inter-item correlations, gave a reliability of 0.933 which signifies high reliability (see Table 1).

Table 6: Cronbach's Alpha

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.933	.945	41

With regard to construct validity in this study, a confirmatory factor analysis was used to check for both convergent and discriminant validity. A factor analysis extraction using the Principal component analysis (PCA) and the Varimax rotation method (to maximize discriminant validity since in orthogonal rotation the items are considered uncorrelated) was carried out to check and control for Common method bias (CMB). The resulting Kaiser-Meyer-Olkin (KMO) measure of sampling

adequacy was greater than the minimum 0.5 indicating that the items had good discriminant and convergent validity. In addition, Bartlett’s Test of Sphericity was statistically significant ($p < 0.05$) thus indicating the suitability of the factor analysis (see Table 2).

Table 7: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.895
Bartlett's Test of Sphericity	Approx. Chi-Square	4848.719
	df	741
	Sig.	.000

Regression Model

The basis of this model was to show that Effort Expectancy (TEE), Performance Expectancy (TPE), Social Influence (TSI), Facilitating Conditions (TFC), Habit (THBT), Perceived Relevance (TPR), Nature of Feedback Language (TNFL), Perceived Importance (TPI), Hedonic Motivation (THM), and Self – Efficacy (TSE) have an influence on Behavioral Intention. The behavioural intention that we focus on in this study is the use and acceptance of formative assessment feedback by third year pre-service teachers in an online undergraduate course.

A stepwise multiple regression analysis was conducted to evaluate whether THM, TPR, TFC, TPI, THBT, TEE, TSE and TNFL were necessary to predict Behavioral Intention of using and accepting feedback by pre-service teachers in an undergraduate Online course. At step 5 of the analysis THM, TPR, TFC, TPI, THBT entered into the regression equation were significantly related to Behavioral Intention(BI), $F(5,208) = 52.178$, $p < .001$. The multiple correlation coefficient (R) was .0.746, and (R²) was 0.556 indicating approximately 55.6% of the variance of the Behavioral Intention could be accounted for by the predictor variables. The Durbin-Watson value is 2.013 which is approximately equal to two (2) indicating the assumption of independent errors is plausible thus making our predictive model accurate (see Table 3 and Table 4).

Table 8: Regression Model Summary

Model Summary ^f					
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.624 ^a	.390	.387	1.926	
2	.700 ^b	.490	.485	1.765	
3	.720 ^c	.519	.512	1.719	
4	.735 ^d	.540	.531	1.684	
5	.746 ^e	.556	.546	1.658	2.013
a. Predictors: (Constant), THM					
b. Predictors: (Constant), THM, TPR					
c. Predictors: (Constant), THM, TPR, TFC					
d. Predictors: (Constant), THM, TPR, TFC, TPI					
e. Predictors: (Constant), THM, TPR, TFC, TPI, THBT					
f. Dependent Variable: TB1					

Table 9: ANOVA for Model 5

ANOVA ^a						
Model		Sum of Squares	df	Mean Square	F	Sig.
5	Regression	717.053	5	143.411	52.178	.000 ^f
	Residual	571.681	208	2.748		
	Total	1288.734	213			
a. Dependent Variable: TB1						
f. Predictors: (Constant), THM, TPR, TFC, TPI, THBT						

Table 10: Model 5 coefficients and correlation with Independent variable BI

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations		
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part
5	(Constant)	3.179	.911		3.489	.001	1.383	4.976			
	THM	.223	.060	.239	3.712	.000	.105	.342	.624	.249	.171
	TPR	.141	.062	.167	2.283	.023	.019	.262	.622	.156	.105
	TFC	.139	.048	.188	2.919	.004	.045	.232	.603	.198	.135
	TPI	.082	.026	.169	3.151	.002	.031	.133	.494	.213	.146
	THBT	.144	.053	.183	2.750	.006	.041	.248	.581	.187	.127

In Table 5, the coefficients of THM, TPR, TFC, TPI and THBT are 0.223, 0.141, 0.139, 0.082 and 0.144 respectively. These coefficients represent the change in the BI variable when there is one unit change in one of the independent variables (THM, TPR, TFC, TPI or THBT) when other predictor variables are held constant. The constant 0.317 is the value of the BI when all the predictor's variables are equal to zero.

Table 11: Model 5: Multicollinearity

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
5	(Constant)	3.179	.911		3.489	.001		
	THM	.223	.060	.239	3.712	.000	.512	1.952
	TPR	.141	.062	.167	2.283	.023	.401	2.496
	TFC	.139	.048	.188	2.919	.004	.514	1.945
	TPI	.082	.026	.169	3.151	.002	.739	1.354
	THBT	.144	.053	.183	2.750	.006	.483	2.069

The variance inflation factor (VIF) quantifies the extent of correlation between one predictor and the other predictors in a model. It is used for diagnosing collinearity/multicollinearity. Higher values signify that it is difficult to impossible to assess accurately the contribution of predictors to a model. A value of 1 means that the predictor is not correlated with other variables. The higher the value, the greater the correlation of this variable with other variables. Values of more than 4 or 5 are sometimes regarded as being moderate to high, with values of 10 or more being regarded as very high. Considering Table 6, variance inflation factor (VIF) values are less than 5 meaning that there is no multi-collinearity in the data, a precondition for multiple regression. The resulting regression equation is:

$$BI = 3.179 + (0.223 * THM) + (0.141 * TPR) + (0.139 * TFC) + (.082 * TPI) + (.144 * THBT)$$

The implication of these findings is that hedonic motivation, perceived importance, perceived relevance, facilitating conditions and habit are important factors in pre-service teachers' behavioral intention to accept and use online formative assessment feedback during authentic tasks in their undergraduate course. According to the UTAUT2 model, behavioral intention (BI) is a direct determinant of use behaviour (Venkatesh et al., 2012). Furthermore, in the original UTAUT2 model effort expectancy, performance expectancy, social influence, hedonic motivation and habit are antecedent of behavioral intention. However, in this study, effort expectancy, performance expectancy and social influence have no influence on behavioral intention. On the other hand, hedonic motivation, and the newly hypothesized constructs, perceived relevance and perceived importance, facilitating conditions, and habit have significant influence on behavioral intention to use formative assessment feedback.

The construct of hedonic motivation accounts for the largest variation, i.e. 39% out of 55.6% (see Table 3) thus indicating that it is the most important of behavioral intention to use and accept online formative feedback. This unexpected finding is inconsistent with many UTAUT2 studies (c.f. Liu et al., 2015; Venkatesh, et al., 2003; Venkatesh, et al., 2012). The other constructs that were hypothesized to have an influence on the behavioral intention to use formative assessment feedback, namely self-efficacy and nature of feedback language were also found to have no influence on the behavioral intention to use formative assessment feedback in this study.

CONCLUSION

This research aimed to investigate the factors that are important in pre-service teachers' decision in an undergraduate online module to accept and use formative assessment feedback during authentic tasks. The findings of this study do not support the view that Effort Expectancy, Performance Expectancy, Social Influence and Self-Efficacy have an influence on Behavioral Intention (see Lu, Lin, & Li, 2016; Liu et al., 2015; Williams, Rana & Dwivedi, 2015; Venkatesh, Thong, & Xu, 2012; Venkatesh, Morris, Davis, & Davis, 2003). Findings rather support the view that Facilitating Conditions (TFC), Habit (THBT), Perceived Relevance (TPR), Perceived Importance (TPI), and Hedonic Motivation (THM) have a greater influence on Behavioral Intention in this context (see regression equation for model 5). Researchers and lecturers will find the study useful since it introduces for first time how variables like Hedonic Motivation and Habit have an influence on Behavioral Intention. This is consistent with the findings of Venkatesh et al. (2012).

The major theoretical contribution of this study is the modification and extension of the UTAUT2 model to cover fields other than technology-based ones (It must be borne in mind that the UTAUT2 has been used previously to evaluate the acceptance of technology and not specifically for constructs such as formative assessment feedback as is the case in this study). In addition, lecturers and instructional designers can now gain new insights into what drives the acceptance and use of

formative assessment feedback in authentic tasks within online modules. With this newfound understanding they can now target appropriate interventions in relevant areas in order to enhance online formative assessment feedback. On an institutional level, the five relevant predictors of behavioral intention to use formative feedback higher education institutions can now be introduced to provide conducive conditions to enhance the acceptance and use of formative feedback by students.

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MAKING A DIFFERENCE OR NOT: TECHNOLOGY TEACHERS' PROFESSIONAL DEVELOPMENT WORKSHOP EXPERIENCES

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ABSTRACT: This phenomenological study enquired into the experiences of the Technology teachers during their professional development workshops focusing on the pedagogical content knowledge (PCK) mapped against the teachers' needs. Phenomenologically, I wanted to understand the experiences of Technology teachers of the workshops from their needs point of view. The workshops were conducted at Nelspruit in Mpumalanga Province of South Africa in 2015. This is the only study conducted in the Province about the teachers' workshops organised and facilitated by the newly established Mathematics, Science and Technology Academy (MST Academy) under the auspices of the Department of Basic Education Mpumalanga. I conducted two focus group interviews with twenty teachers, individual interview with the MST Academy Official (Technology specialist) who facilitated the workshops, and analysed the training manual. Later on two schools were visited to observe and support the teachers who participated in the workshops. The findings revealed that the teachers benefited from the workshops, but the workshops did not always address the teachers' needs regarding PCK, and thus did not address the MST Academy's aim for teachers' professional development desirably. The findings will inform the MST Academy so that appropriate steps can be taken to improve on teachers' workshops.

Keywords: Technology teachers; pedagogical content knowledge; professional development; workshops; needs

INTRODUCTION

This study investigated the Technology teachers' experiences of the professional development workshops at Nelspruit with regards to their PCK. A scarcity of research into the professional development of Technology teachers in South Africa motivated this study. Also, Technology was only introduced for the first time in the school curriculum only two decades ago.

The professional development for teacher education means improving the teachers' skills and competencies that they need to produce the outstanding learner results (Villegas-Reimers, 2003; Mizell, 2010). The teachers' professional development can happen through coaching, lesson observation, professional learning communities, support and hands-on, discussions among work colleagues, independent reading and research, observation of a colleague's work, mentoring (Mizell, 2010, p. 5). The school-based practical experiences with regards to the subject content, new teaching methods required, technological advancement and changing learners' learning needs (Mizell, 2010, p. 6) necessitate professional development of the teachers. However, the teachers' professional development in South Africa is being criticised for a number of reasons such as the teachers less benefited from the many interventions offered (Darling-Hammond, Chung Wei, Andree & Richardson, 2009); under-qualified teachers (Department of Education, 2006; Mapotse, 2012); superficial professional development of teachers (Departments of Basic Education & Higher Education and Training, 2011); low-quality teacher education (Bullough, 2001); professional development is accused for being a mere state-funded skills development programme (Steyn, 2008, p. 3); workshops are brief, fragmented, incoherent, de-contextualised and isolated from the classroom (Villegas-Reimers, 2003). Mouton, Tapp, Luthuli and Rogan (1999) argue that professional development should be tailored according to the needs and expectations of the teachers and

continuous or prolonged. In light of this, there is a need to know if the Technology teachers' workshops make a difference or not in teachers' PCK given their needs.

Since the training of teachers is focused on their PCK, this was adopted as a framework for the study. PCK is a teacher's special attribute displayed in the transformation of the subject matter to make it personally meaningful to learners (Shulman, 1987; Van Driel, Veal & Janssen, 2001). PCK includes the most useful forms of representation of ideas, 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 learners (Shulman, 1987; De Miranda, 2008). The attributes imply the expertise of teachers, which, according to Guerriero (2013), are characterised by extensive PCK, better problem-solving strategies, better adaptation for diverse learners, better decision making, better perception of classroom events, greater sensitivity to context, and greater respect for learners. PCK is an amalgamation of pedagogy and content (what and how), and is the knowledge of teaching (Shing, Saat & Loke, 2015). Technology teachers lack the understanding of the subject content knowledge and pedagogical knowledge and skills (Reitsma & Mentz, 2007; Williams & Gumbo, 2012) especially in the teaching of the design process (investigate, design, make, evaluate and communicate) (Juuti, Rättyä, Lehtonen & Kopra, 2017). Technology's PCK heavily relies on the design process. At Senior Phase (Grades 7 – 9), for example, the subject matter content knowledge consists of Processing of Materials, Structures, Mechanical Systems and Control, and Electrical Systems and Electronics.

According to Shulman (1987), teaching begins with an understanding of what is to be learned and taught. Shulman and Sherin (2004) argue that teaching and learning-to-teach should be subject-specific, hence a specific focus of this study on Technology as a subject. Shulman's (1987) framework consists of the seven teacher knowledge elements, i.e. knowledge of the subject matter, pedagogical content knowledge, general pedagogical knowledge, knowledge of the curriculum, knowledge of the learners and their characteristics, knowledge of the educational contexts, and knowledge of the educational aims, purposes and values. Guerriero (2013) summarises these elements into the general pedagogical knowledge (principles and strategies of classroom management and organisation that are cross-curricular), and pedagogical content knowledge (the knowledge which integrates the content knowledge of a specific subject and the pedagogical knowledge for teaching it). The main focus of this study was on the subject content knowledge and pedagogical knowledge and skills of PCK.

It is necessary for teachers to have a good knowledge of the subject as that will enable them to evaluate textbooks, the technology to be integrated, as well as other teaching resources or mediums of teaching (Banks, 1996; Mishra & Koehler, 2006). Banks (1996, 176) borrows from Shulman to refer to the teaching resources as "the *materia media* or *pharmacopoeia* from which teachers draw their equipment that present or exemplify particular content". Technology integration is the most emphasised matter in the literature as it is perceived as branding teaching for the technology dependent 21st century. In light of this, Mishra and Koehler (2006) extended the PCK to include the integration of technology and thus named the framework the technological pedagogical content knowledge (TPACK). These authors stress the need for teachers to take advantage of the role that technology can play to make teaching effective whilst ensuring that they learn the fast evolution of technology.

The study addressed the following research question: What are the Technology teachers' professional development workshop experiences as regards their PCK vis-à-vis their needs?

RESEARCH METHODOLOGY

This study followed a phenomenological design to describe and interpret the experiences of the participants (Lauwers, 2013; Eddles-Hirsch, 2015). The interpretation of the phenomenon is possible because of the rich description of the same (Eddles-Hirsch, 2015). The focus of the description in this study was on how the participants experienced the phenomenon, i.e. the professional development workshops (Eddles-Hirsch, 2015). The key notions of phenomenology are the participants' experiences and reality, lifeworld, sense-making and sense derivation (Lauwers, 2013; Eddles-Hirsch, 2015). Hence, I was interested in sourcing the participants' experiences and the sense that they made of those experiences. I deemed it necessary to augment or corroborate their experiences with the other types of data sourced from the methods that were mentioned in the abstract of this paper. The Technology teachers' workshops were conducted at Nelspruit in 2015 on two different dates of two-day sessions in order to manage the numbers; each workshop targeted about 30 Grade 9 teachers from two districts. The content of the workshop covered Electronic Systems and Control, Processing and Mini-PAT (i.e. practical assessment tasks based on design process). There were individual and group activities and questions which were based on the electronic components, simple electric circuits and impact of technology. The topic, Processing, was based on the preservation techniques of metals, followed by a few questions, practical task on electroplating, and explanation of the mini-PAT.

Two focus groups of Technology teachers (one in each workshop) were conveniently selected through the facilitator and interviewed for about 40 minutes each. There were 12 teachers in the first group and 8 in the second group. A 30 minute semi-structured interview was also conducted with the workshop facilitator. The interview guides included the biographical information and the main interview items. The training manual was evaluated based on the content and design of the learning activities. Observation was also conducted using an observation tool which targeted the pedagogical approaches, concepts taught and the integration of resources. Two schools were visited ultimately in order to observe the implementation of what the teachers had learned. The interview data were coded, manipulated, summarised and organised into themes to obtain answers to the research questions (De Vos, Strydom, Fouché & Delport, 2011). The multi-method strategy helped to corroborate and triangulate the findings. Presenting the preliminary findings to the MST Academy and peer debriefing with the colleagues at Unisa who teamed up with me in the bigger MST project added to the trustworthiness of the study (Bowen, 2009). The findings were presented under the themes generated according to Bogdan and Biklen (2003, p. 298): preparing the data, reading and re-reading the transcripts, coding the data, segmenting and conceptualising the data according to the emerging patterns; organising the participants' views under the themes for presentation; substantiating the findings with the participants' verbatim statements.

FINDINGS

The participants' biographical information

The teachers' general teaching experience ranged between two and twenty-six years, but between four months and seventeen years for Technology specifically. Four teachers had just started teaching Technology; two had four months experience and two had six months and one year experience each. Teachers were highly qualified in varied fields such as Diploma in Education, Bachelor of Technology (Education Management), Bachelor of Education Honours (Maths), Advanced Certificate in Education in (Maths), Senior Teachers Diploma, Certificate (Maths). As it can be noticed from these few qualifications, the teachers still had to qualify in Technology per se. This state of affairs suggests a need for intense and prolonged workshops to start with, and identification of diploma and degree programmes which teachers can be enrolled in to qualify them as Technology Education specialists.

Themes

Theme 1: The content and activities of the workshop: The facilitator treated the first topic on Electronic Systems and Control, followed by the other two on the following day. He introduced the topic by making reference to real situations in which electronic systems and control are applied such as in cars, and explained logic gates using the flip chart. The next day he gave the teachers an activity to build a simple electric circuit and proceeded with Processing. Specifically to Electronic Systems and Control, the facilitator explained the concept of Logic Gates on the flip chart and engaged the teachers in question-and-answer. The teachers struggled to understand and were passive and gave the wrong answers at times, but later on asked for clarity. Though pressed for time, the facilitator spent some time on the topic to make sure the teachers understood.

The teachers appreciated the learning that they acquired from the workshops, except that they preferred longer and ongoing workshops, e.g. four days per week every beginning term or during the school holidays. On the contrary, the facilitator indicated in an interview that these workshops were planned to continue. The teachers expressed the effects of the brief workshops thus: *Facilitators do not have time to explain and engage us as teachers*. It was observed that the facilitator was pressed for time as he kept saying, *but because of time, ...*. As a result, sections that teachers struggled with were not treated in detail, e.g. mini-PAT, which is basically about the design projects or activities, was only explained and not treated practically. The brief workshops denied the teachers to learn problem content areas such graphics: *I was expecting us to be engaged in drawings*. Teachers primarily struggled with mini-PAT: *Many teachers and learners are struggling with the newly introduced mini-PAT (sic). Most teachers see it as a monster, something difficult to do, and they don't know what to do*. The mini-PAT was included in the training manual with its related concepts, i.e. scenario, investigation, design, make, evaluate and communicate, except it did not have any learning activities.

The fact that content of Technology includes even the basic Physical Science and Mathematics content, the teachers needed to be trained in basic calculations: *I don't have the basics of Physical Science, and sometimes when I am supposed to teach where there are a lot of calculations related to (sic) Physical Science, I sometimes find it difficult. There are calculations of voltage, resistance, current, Ohm's Law, gear ratio, rpm, all of which need basic Mathematics background (sic)*.

When the facilitator treated the preservation of metals under Processing, one teacher explained the process in Isi-Swati (indigenous language) translated: *In the olden days animal fat was used to preserve metals*. Again, because of time factor, the facilitator could not give the teacher enough time to explain more.

Theme 2: On-site observation and support for teachers: The on-site follow-up (support) by the MST Academy itself was non-existent as confirmed in an interview with the facilitator and with the teachers. However, the facilitator indicated that it was included in the MST Academy's schedule of activities. According to the teachers, the subject advisors did not show the school-based support. Teachers specifically expressed their need for assistance during teaching as they felt that they were still struggling with Technology's PCK. This was confirmed when I did school visits (of teachers who attended the training) when one teacher was observed teaching the *design process*. She had assigned learners a project about *Safety* related to the road construction that was taking place about one kilometre away from the school. She asked learners to report what they had done that far in their groups. Learners were merely reading the scenario that had been given. They hesitated to speak and looked unconfident. It appeared that the project brief was not made clear to them in terms of its objectives, resources to be used and the development of tasks. This tells that teachers still struggle about the mini-PAT.

Theme 3: Resources for teaching Technology: As part of the teachers' pedagogical strategies, the availability and integration of the resources is crucial. According to the facilitator, smartboards had been rolled out to school and the teachers had been trained on-site in the use of smartboards. However, the teachers did not know how to use them: *Sometimes we must use smartboards to teach learners. I have no knowledge of that.* At one school visited there was only one smartboard which the teachers "scrambled" over. One teacher confirmed that she did *not know how to use it.* At another school the smartboard was locked away and its accessories had gone missing. In addition, the teachers expressed that the schools were under-resourced especially those in rural areas. The teachers felt that this contributed towards learners' poor understanding of Technology: *Sometimes, we depend on theory.* The absence of resources results in learners *struggling when it comes to drawings because some of them fail to see the top and [sic] side views.*

DISCUSSION

Though the teachers were trained, they had certain preferences about the training. The workshops might have compromised the teachers' needs (Mouton et al., 1999). Though the workshops helped them, they missed out on the crucial content areas especially the mini-PAT as it was observed in one teacher's struggles during the school visits. Design process through which the mini-PAT is taught is the predominant method for teaching Technology. The fact that the teachers' PCK is lacking in this regard as evidenced from the literature (Juuti et al., 2017), the teachers were looking forward to be helped in this regard especially because in the main their profile shows that they have not been formally trained for the subject. Juxtaposing the under-qualification of the teachers (Department of Education, 2006; Mapotse, 2012) to the short time of the workshops adds to the claims made in the literature about this issue. The workshops also fell short from being longer and continuous by a week as per the teachers' views during the interviews, thus confirming the literature (Villegas-Reimers, 2003; Mizell, 2010) which identified the problem. Scholarship in the field is emphatic about the ineffectiveness of the workshops caused by their brevity (Villegas-Reimers, 2003; Bill & Melinda Gates Foundation, 2016). Scholarship also supports the teachers' expressed need for the workshops that last longer (Reitsma & Mentz, 2007). It points to the fact that the Technology teachers' PCK needs more attention, meaning that more time is needed for the teachers to learn in order to acquire the Technology PCK on a more deeper level so they become experts of knowledge and teaching with special attributes (Shulman, 1987; Van Driel et al., 2001; Guerriero, 2013), otherwise the teachers' workshops will not unclaw themselves from being blamed for being but mere state-funded skills development programmes (Steyn, 2008). The workshops did not invest much in the pedagogical aspect – teachers were mostly involved in doing the activities instead of trying out the teaching of the concepts. It is important to consider the notion of PCK being more about presenting the content than the content itself (Shing, Saat & Loke, 2015). Knowing the learners' diversity and context is one of the important elements of Shulman's framework which teachers' workshops should not miss out on – the emphasis of pedagogy can take care of this matter. A training which still treats content separate from the pedagogy counters the progressive work of Shulman's framework. A lack of knowledge and skills to use especially the advanced technological resources such as the smartboard, and a lack of resources themselves is the cry of the teachers. They have to cope with learners who are interested to learn but struggle to understand the subject because it is being taught theoretically. The Technology pedagogy which is hungry for technology integration under-serves the teachers in their training and is inconsiderate of the importance of Mishra' and Koehler's TPACK framework.

CONCLUSION

This study has addressed the stated research question. When considering the MST Academy's aim for the workshops, it surfaced that though the workshops targeted certain subject matter knowledge areas, this aim was not well served mainly because the duration of the workshops was very short, the mini-PAT, which the teachers struggle with, was not treated, the teachers' needs were not met fully, and the workshops did not "enhance" the teachers' PCK as they had expected. It

is therefore recommended that the preparation for the future workshops should begin with exploring the teachers' professional development needs so the workshop content can be designed by taking their needs into account. Serious consideration should be given to the longer workshops to ensure that teachers acquire the required knowledge and expertise to be the masters of the subject content and pedagogical knowledge and skills. Teachers should also be given the opportunity to try out and critique lesson preparation and presentation – the workshops should be more about how to present the content than the what. The MST Academy should ensure that ongoing support is given when the teachers implement what they have learned because that way the MST Academy will know if the workshops are making any difference or not in the professional development and PCK of teachers. The MST Academy should come up with the plan to upgrade teachers' qualifications, e.g. enter into an agreement with the higher education institutions so that the teachers can enrol for a specialised training which will qualify them or upgrade their qualifications in Technology.

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UNDERSTANDINGS REVEALED BY ENGINEERING STUDENTS' ACTIONS IN A CAS TASK

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ABSTRACT: Understanding is a continuous pursuit of making sense of lived experiences. We considered how a mathematical modeling task could invite varied levels of understanding. When engineering students learn in a computer algebra system environment, they often jump straight into programming activities and struggle to make sense of computerised outputs. This paper aimed to identify actions that can mediate broader levels of understandings. We used the Pirie-Kieren model of growth in mathematical understanding to identify the actions of engineering students registered at a South African university. Thirteen participants voluntarily collaborated to work on a modeling task, which was deductively analysed using content analysis. The findings revealed an interdependence between paper-and-pen, computerised and reflective actions in the development of understandings. Scaffolded and folding-back actions can assist students to oscillate back and forth towards more cogent understandings. Specific arrangement and sequence of subtasks can assist students to reconcile new understandings with past understandings. Well-designed modelling tasks can facilitate unconventional levels of understanding when students learn with a computer algebra system.

Keywords: Computer algebra system; differential equations; engineering students; Pirie-Kieren model; real-world contexts

INTRODUCTION AND BACKGROUND

Learning with a computer algebra system (CAS) is acknowledged as a fundamental tool for future engineers. When engineering diploma students at the University of Johannesburg (UJ) are first exposed to CAS, they find it problematic to interpret computer-generated graphs. The transition from a paper-and-pen learning background to a CAS environment can be problematic. Berger (2010) argued that the epistemic value of certain processes may be high in a paper-and-pen environment but minimal in a CAS environment. Different skills are needed to interpret computer-generated outputs as compared to the interpretation of graphs produced by paper-and-pen. The interpretation of CAS graphs requires conceptual skills that must be developed through appropriate tasks (Artique, 2002). Interventions have been suggested to improve the facilitation and articulation of understandings in computational settings. In order to curtail CAS-related difficulties, Noss, Healy and Hoyles (1997, p. 207) suggested mediational tasks that encourage students to construct “links between seeing, doing and expressing” while Kieran and Saldanha (2008) recommended activities that draw on students’ prior knowledge and skills. Activities wherein computer outputs are tested and explained can prompt students to reflect on, and reconcile their paper-and-pen actions with CAS results. According to Stillman (2015), CAS technologies add to the complexity of tasks and therefore suggests that the cognitive demand imposed by real world problems be mediated through well-crafted mathematical modeling tasks. Conversely, there is a paucity of research on mathematical modeling as mediation for the cognitive demands imposed by a CAS learning environment. This study is devoted to this gap and asks the question: *Which actions can facilitate broader levels of understanding in a CAS task?*

THEORETICAL PERSPECTIVES

A mathematical modeling approach considers a real life problem in which mathematics serves as content to solve a realistic solution (Kaiser & Schwarz, 2010). This approach is contrary to conventional classroom practices where mathematics is often presented as a world apart from reality. For engineering students, the purpose of a mathematical modeling approach is to solve complex problems and validate the appropriateness of solutions. A modeling approach elicits an interplay between the real world and the world of mathematics. The real world problem has to be translated into a mathematical model, a process called mathematizing (Freudenthal, 1991). Ultimately, the mathematical solution must be interpreted in relation to its real world meaning.

Pirie and Kieren (1994) regard understanding as dynamic process and catalogue eight levels of sophistication namely, Primitive knowing (PK), Image making (IM), Image having (IH), Property noticing (PN), Formalising (F), Observing (O), Structuring (S) and Inventising (I). Fig. 1 depicts the eight levels of understanding in the model as proposed by Pirie and Kieren (1994). PK is the beginning of the understanding process and involves baseline, entry-level or intuitive understandings that will set students' coming to know in motion. On the level of IM, images are formed as a result of previous 'doing' and 'knowing'. These images may involve mental images or concrete images that reflect understandings of a concept. IH does not necessarily imply complete and correct understandings of images but making use of images already formed. On the level of PN, images are inspected for characteristics and notable trends. In the case where multiple images were formed for a certain concept, distinctions, comparisons and connections can be made. The F level involves the use of definitions, equations, formulas or models. On the O level, thoughts are organised and must be consistent with inner levels of understanding. The S level contemplates the truth, validity and justification of all acquired thoughts which are now inter-related. The I level is the outermost level of understanding when considerations beyond the intended domain of knowledge is being probed; understandings are inventive, imaginative and innovative.

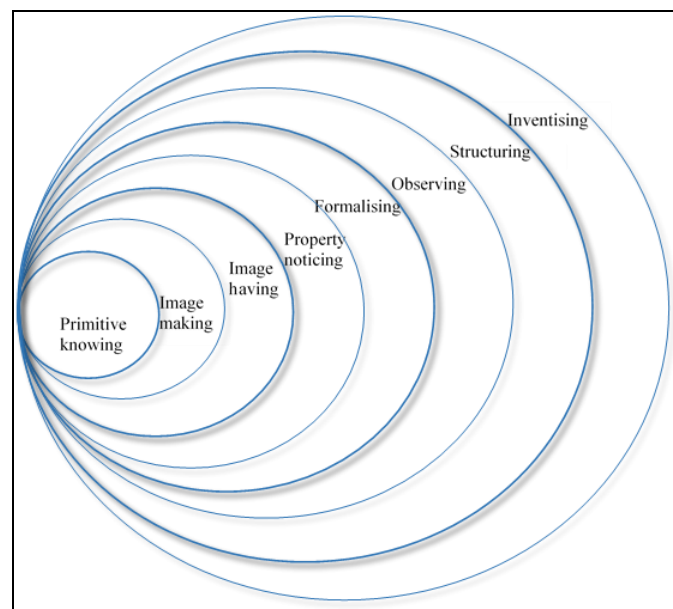


Figure 1: The Pirie-Kieren (1994, p. 167) model of growth in mathematical understanding

The fractal-like quality of the Pirie-Kieren model in Figure 1 suggests that at each level, layers are nested. The outer layers depend on understandings of the foregoing, inner layers. Levels are not hierarchical. Understanding at an outer level is not necessarily 'higher' than understandings formulated at an inner level. Understandings at a certain level may also 'bypass' certain inner levels.

RESEARCH DESIGN AND METHODOLOGY

We subscribed to a contextualist world view where intuitive understandings can be a rich source to contextualise learning activities (Schraw, 2013). Realities encountered in daily life characterise the nature of knowing but also implore students' ways of doing and understanding. The research methodology is exploratory with a qualitative undertone. The study formed part of a broader research project that investigated the influences of mathematical modeling in a CAS environment.

Engineering Mathematics 3 students learn how to solve differential equations (DEs) numerically with Mathematica, a type of CAS. Once every week of the semester, students have to attend a practical session of 150 minutes in a computer laboratory. We analysed how engineering students had connected their intuitive knowledge, mathematical understanding and technological skills when they had solved a differential equation (DE) that related to a real world problem. From a 2016 cohort of 139 students, thirteen students participated voluntarily in this study. Participants were in their second year of study and registered for a National Diploma in Electrical Engineering at UJ. Two groups were formed by using prior assessment results; each group included low, average and top performers.

This paper reports on one of the modeling tasks. The tollgate problem narrated the annual exodus of pilgrims over the Easter weekend to the city of Moria, SA. The N1 National highway between the cities of Pretoria and Bela-Bela is notorious for traffic congestion, partly due to four tollgates. The differential equation (DE) that models the traffic flow on this stretch of road was given as

$$\frac{dN}{dx} = 350 \cos \frac{2\sqrt{x+0.15}}{\sqrt{x+0.15}} \text{ where } N \text{ indicates the density of vehicles and } x \text{ the position on the road.}$$

The task was completed shortly after the Easter weekend in 2016. For the purpose of this paper, the worksheet and task report of one group were analysed using content analysis. The Pirie-Kieren levels of understanding were used as categories to code the actions of these students. The task was delineated into eight subtasks.

In subtask *one*, the narrative describing the tollgate phenomenon had to be interpreted. Students had to use their personal experiences relating to toll roads to consider how traffic would be affected by four tollgates on a 105km stretch of road. In subtask *two*, students had to derive an initial condition (IC) for the DE by translating the clue: "assume there are 945 vehicles at the first tollgate". Usually, the IC is given and students merely have to substitute the IC into the DE. In subtask *three*, students had to predict the solution without doing any formal analyses. In subtask *four*, the DE had to be solved analytically and a CAS graph (sinusoidal) generated. In subtask *five*, the latter graph had to be compared with the solution as predicted in subtask three. Supported by the analytical solution, subtask *six* required students to find the maximum number of vehicles that gathered at a tollgate. This subtask required a real-world interpretation of the sinusoidal graph. In subtask *seven*, the Runge-Kutta order 4 (RK4) numerical method had to be programmed from first principles. Subtask *eight* posed the question: 'Is there a tollgate at the 50km mark? Why.' In subtask *nine*, the distance between the last two tollgates on the road had to be calculated.

DATA ANALYSIS

In subtask one, students sketched (action 1) a primitive diagram to illustrate the four tollgates on the N1 highway (Fig. 2-Left), revealing intuitive understanding of how tollgates affect the flow of traffic. The narrowing effect resembles the high density of vehicles as traffic bottleneck at the tollgates. These students labelled (action 2) the traffic density as "high" or "low"; these descriptions were visual clues that could help with subsequent understandings. Fig.2 (Left) depicts the qualitative nature of the tollgate phenomenon and thereby, students mathematised (action 3) the real world problem. These first impressions and understandings were established on the Pirie-Kieren level of PN. In subtask two, students relied on the given narrative to interpret (action 4) the IC symbolically. It is likely that the high-low properties noticed in their primitive diagram supported the translation of

the real world narrative and paved the way to formulate (action 5) the IC. In subtask three, understandings veered to the PN level when the solution was predicted (action 6). By drawing (action 7) a negative exponential graph, students envisaged a gradual decrease in traffic over time. It appears that students imagined (action 8) a long-time solution of traffic over the four-day period of the Easter weekend. In subtask four, the DE was solved (action 9) analytically using the separation of the variables method. The DE was simplified (action 10) by substituting the IC to obtain a sinusoidal solution $N = 350\sin(2\sqrt{x} + 0.15) + 700.2 \dots$ Eq. 1.

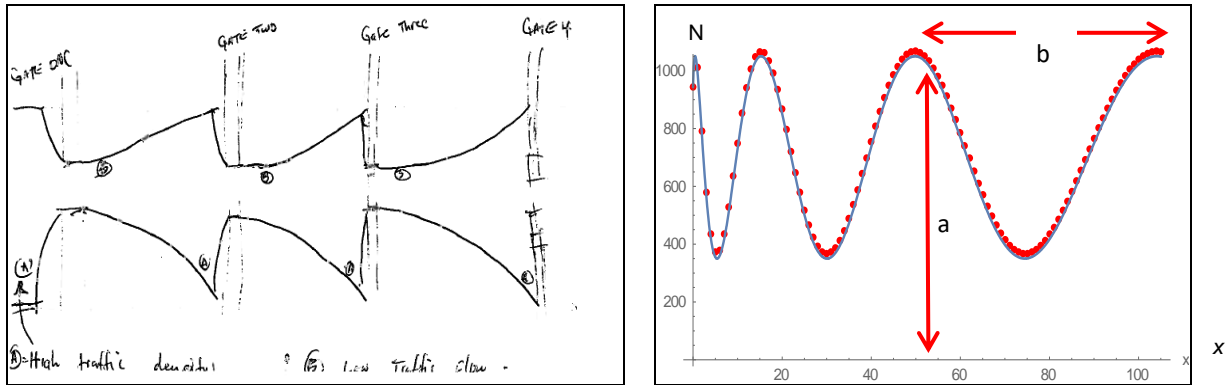


Figure 2: Left – the primitive diagram created in subtask one. Right – CAS graph to a) read off a tollgate at 50 km mark and b) calculate the distance between the last two tollgates.

In subtask five, students compared (action 11) the analytical solution with the solution as predicted in subtask three. At this junction, students struggled to reconcile (action 12) the sinusoidal solution with their exponential drawing. In order to validate (action 13) the solution, they generated (action 14) a CAS graph for the analytical solution and identified (action 15) the function: “it looks like a sine graph”. Faced with two opposing solutions, they reviewed (action 16) their solutions: “is it sine or exp?” To this end, students combined (action 17) their primitive diagram with the exponential drawing by superimposing (action 18) a decreasing exponential function onto the primitive tollgate diagram. This way, they illustrated their understanding of the diminishing traffic density towards the end of the Easter weekend. With the superimposed image, these students’ understandings went beyond the scope of the intended task and bordered on the Pirie-Kieren level of inventising. In subtask six, students predicted (action 19) the maximum number of vehicles that gathered at any tollgate to be “approximately 994”. From their task report, it was clear that they (mis)calculated (action 20) this value by substituting $x = 1$ into Eq.1. Since the maximum possible value of the first term in Eq. 1 is 350, the correct answer would be $350 + 700.2 = 1050.2$. In subtask seven, the RK4 algorithm had to be constructed from first principles. Students programmed (action 21) the Mathematica code and generated (action 22) numerical values and a graph. Hence, they could compare (action 23) the RK4 numerical values with the analytical values; this graph is displayed in Fig. 2 (Right). In subtask eight, students interpreted (action 24) the latter figure and explained (action 25) why there should be a tollgate at the 50km mark. They read off (action 26) the value of N when $x = 50$ and confirmed (action 27) a tollgate at that position on the road. This fact was substantiated (action 28) by referring to their table of RK4 values. In subtask nine, the distance between the last two tollgates were read off (action 29) using Fig. 2 (Right), thereby justifying (action 30) that maxima of the sine curve indicated to the position of tollgates.

Table 1 summarises the 30 sequential actions as categorised according to the Pirie and Kieren (1994) levels of understanding. A distinction was made between experiential and reflective actions; experiential actions were further sub-divided into computerised actions or paper-and-pen actions. The majority of actions were performed with paper-and-pen ($n = 15$), followed by reflective actions ($n = 12$) while the least number of actions performed were computerised ($n = 3$). It is noteworthy

that within the first 20 actions, these students performed only one action (action 14) with the help of Mathematica. In contrast, most activities are executed with CAS in the traditional learning approach, thus operating mostly on the F level of the Pirie-Kieren model. All eight Pirie-Kieren levels of understanding were visited but even more unusual, all eight Pirie-Kieren levels of understanding were appropriated within the first 19 actions. In other words, with the exception of action 14, all Pirie-Kieren levels of understanding were visited *prior* to CAS activities. Most understandings were unpacked on the PN level (5 actions), F level (6 actions) and O level (6 actions).

Table 1: Thirty actions that were recorded

Pirie-Kieren level (n = 8)	Experiential actions (n = 18)		Reflective actions (n = 12)
	Computerised (n = 3)	Paper-and-pen (n = 15)	
Primitive knowing (PK)		1. Sketch; 2. Label; 3. Mathematise	
Image making (IM)		7. Draw; 17. Combine	8. Imagine; 13. Validate
Image having (IH)	14. Generate		23. Compare
Property noticing (PN)		4. Interpret; 6. Predict 29. Read off	12. Reconcile; 15. Identify
Formalising (F)	21. Programme 22. Generate	5. Formulate; 9. Solve 10. Simplify; 20. Calculate	24. Interpret; 25. Explain 27. Confirm; 28. Substantiate
Observing (O)		19. Predict; 26. Read off	
Structuring (S)			11. Compare; 16. Critique; 30. Justify
Inventising (I)		18. Superimpose	

DISCUSSION

The modeling task was unlike the traditional computer laboratory approach where abstract DEs are solved using numerical methods and CAS. Instead, the task grounded a DE as a real world phenomenon and elicited students' experiential understandings. While the underlying mathematics of the tollgate task was relatively simple and the Mathematica code-writing a familiar process, additional subtasks added a modeling flavour. For most of the task, the students used CAS sparsely to verify understandings with paper-and-pen and reflective actions. This finding is supported by Dubinsky and Tall (1991) claiming that parallels should be drawn between programming actions and the way underlying mathematical processes are constructed. The subtasks charted the way to traverse between mathematical concepts, CAS tools and real world contexts as these students seemed to draw on reality throughout the task. The genesis of these students' understandings came in the form of a primitive but thought-provoking diagram (Fig. 2-Left). Underscored by all eight Pirie-Kieren levels of understanding, actions were in sync with the real world contexts of the task. Understandings were verified by paper-and-pen, executed with technology and supported by ample reflective actions. It was striking how 1) the tollgate phenomenon was visually imagined; 2) the primitive model offered understandings of the task and 3) the real world scenario were mathematised, prior to CAS analyses.

The findings *firstly* indicate to an interdependence between paper-and-pen, computerised and reflective actions in the development of understandings. Not only did students combine their computerised actions with paper-and-pen actions, but due to multiple paper-and-pen actions they could also deeply reflect on their CAS outputs. The interaction between computerised, paper-and-pen and reflective actions enhanced these students' interpretation of their computer-generated graphs. This finding is consistent with Drijvers (2003) who observed that students' reflection by way

of paper-and-pen actions can potentially improve their understanding of how computerised processes work and thereby enrich the interpretation of computerised outputs. As a direct result of paper-and-pen actions, these students' understandings were frequently reinforced on the Pirie-Kieren levels of PK, PN and F (Table 1). Due to rich reflective actions, their understandings were further conceived on the Pirie-Kieren levels of O and S. It is noteworthy that although these students performed the task with minimal computerised actions (only 3 actions), they garnered substantial support from paper-and-pen and reflective actions. In comparison, the traditional computer laboratory approach is largely driven by computerised actions. As such, broader levels of understanding can emerge when computerised actions are underpinned by paper-and-pen actions *and* supported by reflective actions.

The findings *secondly* indicate that the way the tollgate task was delineated into subtasks accrued growth in understanding. Even when a particular subtask was completely incorrect (subtask three), understandings could be revised, reflected upon and/or improved. Pirie and Kieren (1994, p. 173) dubbed the back-and-forth nature of understandings as "folding back", describing it as follows:

when faced with a problem or question at any level, which is not immediately solvable, one needs to fold back to an inner level in order to extend one's current, inadequate understanding. This returned-to, inner level activity, however, is not identical to the original inner level actions; it is now informed and shaped by outer level interests and understandings.

When understandings that were shaped in subsequent subtasks were still fragmented, these understandings could be rerouted to understandings formulated in preceding subtasks (Table 1). Collectively, the series of scaffolded and folding-back actions helped students to oscillate back and forth towards more cogent understandings. In this sense, the specific arrangement and sequence of subtasks helped students to reconcile new understandings with past understandings. This finding resonates with Vandebrouck (2018) who believe that subtasks can play a mediating role in tasks involving technology.

CONCLUSION

Historically, mathematical procedures may have been paper-and-pen driven but future engineers will be expected in their world of work to apply theoretical concepts to solve real world problems with the use of technology. Even within its limited scope, this research found that paper-and-pen and reflective actions were inspired by the modelling nature of the tollgate task while subtasks facilitated broader levels of understanding. The potential of well-designed CAS tasks are yet to be untapped.

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LEARNING STYLES AND TECHNOLOGY ACCEPTANCE

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ABSTRACT: Students differ in terms of their learning style, which implies that their technology acceptance may be influenced by their individual learning styles. Several researchers have proposed that learning style, teaching style and learning-teaching fit would have an effect on the relationship between determinants of technology acceptance and behavioural intention, but there seems to be a lack of tested models in the literature. This study aimed to propose and test a model where the moderating effect of learning-teaching fit on the relationship between determinants of technology acceptance and behavioural intention is considered. The acceptance of an e-learning tool was considered in this study. A cross-sectional survey design was used and a total of 257 usable responses were received. It was found that some of the learning style dimensions show a moderating effect on technology acceptance. It was further found that the proposed model did not display a good structural model fit to the data in this study. This study enables improved understanding of the factors that may aid or hinder the adoption of an e-learning tool and emphasizes the necessity of further research on the effect of learning styles and teaching styles on the acceptance of e-learning tools.

Keywords: Learning styles; learning-teaching fit; technology acceptance; SLMS

INTRODUCTION

Universities have an obligation to integrate technology in meaningful ways in order to deliver deeper, active learning experiences. In addition, adaptive technologies are needed that support personalization of students' learning experiences (Becker et al., 2017; Johnson et al., 2016). E-learning is defined as learning facilitated and supported through the utilization of information and communication technologies (ICTs). It includes use of ICT-based tools (e.g. Internet, computer, telephone, radio, video, and others) and content created with technology (e.g. animations) to support teaching and learning activities (Umrani-Khan & Iyer, 2009). Specialized Learning Management Systems (SLMS) show promise in terms of both e-learning and adaptive technologies.

However, students differ in terms of their learning styles (Felder & Soloman, 1999) which implies that their technology acceptance may be influenced by their individual learning styles. Furthermore, lecturers each have their preferred teaching style, which may or may not fit the learning styles of the students they teach. Several researchers have proposed that learning style, teaching style and learning-teaching fit would have an effect on the relationship between determinants of technology acceptance and behavioural intention. However, models, such as EduBIM (Lin, Lu, & Liu, 2013) and ELAM (Umrani-Khan & Iyer, 2009) have not been tested and furthermore, a gap in the literature seems to exist regarding the effect of learning and teaching style on the relationship between determinants of technology acceptance and behavioural intention. Therefore, the question persists: Does the fit between learning and teaching style (learning-teaching fit) influence the acceptance of technology? This study aimed to propose and test a model where the moderating effect of learning-teaching fit on the relationship between determinants of technology acceptance and behavioural intention is considered.

THEORETICAL BACKGROUND

In this section, learning style and technology acceptance theories and models and related studies are discussed.

Learning Style

University students come from different social and knowledge backgrounds and therefore have different responses to specific classroom environments and instructional practices (Becker et al., 2017; Johnson et al., 2016). A deeper understanding of how students approach new material, in other words their learning styles, can aid in delivering deeper, active learning experiences. Felder and Brent (2005) defined a learning style as the way in which an individual acquires, retains and retrieves information and serves as an indicator of how students perceive, interact with and respond to the learning environment. Learning styles are not differences in students' abilities, but rather preferences for processing information in certain ways (Willingham, Hughes, & Dobolyi, 2015).

The use of learning styles in teaching is a controversial subject and the validity thereof is routinely challenged in the psychology literature (Felder, 2010). Some people claim that it is a myth that teaching students according to their style will result in improved learning and they continue by saying that there is currently no evidence to support it (Newton & Miah, 2017; Willingham et al., 2015). However, others declare that the most common learning styles models have been used frequently and successfully to aid educators in designing effective instruction, to help students better grasp their own learning processes, and to assist both educators and students in appreciating that not everyone is alike (Ceccucci, Hunsinger, Kruck, Peslak, & Sendall, 2016; Felder, 2010).

Felder and Soloman (1999) developed the Index of Learning Styles questionnaire (ILS) to describe the learning style preferences of students in four dimensions. The classification of these dimensions is based on the type of information received (sensing or intuitive), the modality through which information is perceived (visual or verbal), the manner in which information is processed (actively or reflectively) and the progression towards understanding (sequentially or globally).

Numerous studies that are concerned with learning styles have been done in various fields. The focus of this literature review is on studies regarding computing sciences and learning styles. Al-Saffar (2014) conducted research on computer science and business informatics students at the University of Potsdam in order to suggest a better learning environment that meets most of the students' learning style preferences in an attempt to reduce the dropout rate. He noticed differences in the preferences of learning styles between male and female students of different study fields at the computer science department, as well as differences between students with different specialties, for example: female business informatics students are more active learners than the students in computer science are. Especially the male computer science students have a slightly greater tendency towards being strong visual learners. Male students from both computer science and business informatics are more balanced with none of the business informatics students being moderate or strong intuitive learners. The male computer science students have a tendency of being intuitive learners. It seems as if the computer science students have a tendency towards being global learners while the business informatics students appear to be sequential. Mironova, Amitan, Vilipold, Saar, and Ruutmann (2013) proposed that practical assignments that fit in with the students' learning styles should be given to students. To active learners they proposed group work assignments, to sensing learners, exercises that were connected with solving real problems and a visual representation of course material was proposed for visual learners. They claimed that this flexible adaptive learning approach improved the quality of educational material and enhanced the educational effect of the use of innovative teaching methods.

Several studies have focused on learning styles, adaptive teaching styles and student performance. However, in this study we do not focus on teaching students according to their learning style for improved learning. In this study, our focus is on the acceptance of an e-learning tool and the

moderating effect of the learning style dimensions of the Felder-Silverman learning style model (Felder & Spurlin, 2005) on their acceptance.

Technology acceptance

The research of user acceptance of new technology gave rise to a number of models. It started with the theory of reasoned action (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975) followed by the theory of planned behaviour (Ajzen, 1991). In the technology acceptance model (TAM), Davis, Bagozzi, and Warshaw (1989), identified and measured usefulness and ease of use. An extension to TAM, namely TAM2, added subjective norm and voluntariness (Venkatesh & Davis, 2000). Rogers (1995) establishes in the diffusion of innovation (DOI) theory that decisions to adopt or reject an innovation are based on the beliefs users form about the innovation.

In the Unified Theory of Acceptance and Use of Technology (UTAUT), Venkatesh, Morris, Davis, and Davis (2003) reviewed and synthesized eight theories/models of technology use to formulate the unified model. The UTAUT was developed with the factors listed and defined in Table 1.

Table 2: The UTAUT model (Venkatesh et al., 2003)

Factor	Definition
Performance expectancy	The degree to which a person believes that using the system will help him/her to better his/her performance and therefore enhance the quality of his/her work (Venkatesh et al., 2003)
Effort expectancy	The degree of ease that is associated with the use of a certain system (Venkatesh et al., 2003)
Social influence	Refers to the degree to which a person experiences interpersonal influence to use a system from important people within his/her social environment (Venkatesh & Davis, 2000)
Facilitating conditions	“the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system” (Venkatesh et al., 2003).
Self-efficacy	A person’s belief in his/her own ability to succeed in a specific situation or to accomplish a task (Bandura, 1995)
Anxiety	A sense of worry, nervousness, or unease about something with an uncertain outcome
Attitude towards using technology	A person’s overall affective reaction to using a system (Venkatesh et al., 2003)
Voluntariness of use	“the degree to which use of the innovation is perceived as being voluntary, or of free will” (Moore & Benbasat, 1991)
Behavioural intention	An individual’s intention to use an innovation in the future, whether or not he or she used it currently (Ajzen, 1991)

In UTAUT2, Venkatesh, Thong, and Xu (2012) extended the UTAUT model and included the constructs price value, habit and hedonic motivation to study acceptance and use of technology in a consumer context. Since students’ acceptance of an e-learning tool does not fit into a consumer context, this study made use of the original UTAUT (Venkatesh et al., 2003).

Chen (2011) considered educational compatibility (the unique learning expectancies of students) in his study and found that educational compatibility had a greater total effect on e-learning acceptance than technological expectancy. Benadé and Liebenberg (2017) reiterated that e-Learning Compatibility should be taken into account while studying technology acceptance in educational settings.

Lin et al. (2013) proposed a model, EduBIM (Education Behavioural Intention Model), that focuses on the degree of correspondence between students’ perceived learning and teaching styles, which

together directly moderate the intention and usage of e-learning systems. However, proof that EduBIM was tested could not be found.

The Proposed Model

The model (see Figure 1) proposed and tested in this study is based on UTAUT (Venkatesh et al., 2003), EduBIM (Lin et al., 2013) and findings of previous research by Liebenberg, Benadé, and Ellis (2018) and Benadé and Liebenberg (2017).

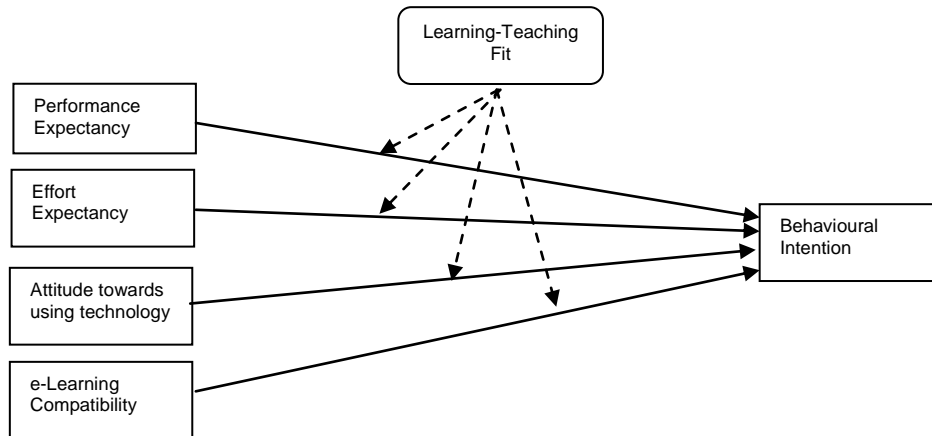


Figure 1: Proposed model

The inclusion of determinants of Behavioural intention in the model can be explained as follows: Performance expectancy and Effort expectancy were included in all the above studies, and were therefore essential factors to include in our model; Benadé and Liebenberg (2017) found Attitude towards using technology to be the dominant determinant of Behavioural intention; Chen (2011) and Benadé and Liebenberg (2017) called for the inclusion of e-Learning Compatibility specifically in educational settings.

EduBIM (Lin et al., 2013) considered Learning-Teaching Fit in the proposed model but since the results of the testing of the model could not be found, we were particularly interested in the moderating effect of these factors.

METHODOLOGY

In this section, the demographics of the participants will first be explained, followed by the data collection and analysis and finally the results will be discussed.

Settings and participants

A cross-sectional survey design was used to conduct this study at the North-West University in South Africa. A convenience sampling technique was applied and the participants were first-year BCom students, all taking a first semester ICT course in 2018, called "Introduction to End-User Computing". There were two groups of students totalling 554 students, who were taught by the same lecturer. A total of 257 usable responses to the online questionnaire was received, indicating an overall response rate of 46.4%.

An e-learning tool also called a specialised learning management system (SLMS) was introduced at the beginning of the semester. The SLMS is an interactive, online learning environment that helps students to master Microsoft Excel and other computer concepts. Students use the SLMS tool to observe live applications, then practise these applications and thereafter apply their skills in short questions and projects. Projects are scheduled with deadlines for submissions and a variable number of resubmissions as determined by the lecturer are allowed. An auto-grading system grades the

projects and a reporting tool gives immediate feedback, providing the students with an opportunity to make corrections and resubmit.

The SLMS can be described in terms of the four dimensions of Felder and Soloman (1999). The type of information received is facts and expects students to solve problems using standard procedures. The modality through which information is presented is mostly through videos, pictures, diagrams, demonstrations and rich multimedia simulations. Furthermore, verbal explanations are offered by a narrator. The SLMS expects of students to process information by applying knowledge and practising skills quietly on their own. The SLMS further expects of students to progress towards understanding in small linear steps.

Instrument, data collection and analysis

Two instruments were used in this study: the Index of Learning Styles questionnaire (ILS) of Felder and Soloman (1999) and a questionnaire regarding the acceptance of the SLMS tool based on Venkatesh et al. (2003) and Chen (2011) where the following determinants of Behavioural intention (BI) were considered: Performance expectancy (PE_{Ex}), Effort expectancy (E_{fEx}), Attitude towards using technology (Att) and e-Learning compatibility (EC).

The ILS assessed preferences on four dimensions (Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global) of which groups of 11 questions relate to each of the four dimensions. There are 44 questions where each question has an a) and b) option from which to choose. According to Felder and Soloman (1999) the prescribed method of recording the score is to get the difference between the total of all the a) and all the b) scores of each dimension. For example, if the total of the a) scores of the dimension Active/Reflective is 5 and the total of the b) scores is 6, the final score will be 1b) The ILS was completed by both the lecturer and the students and the degree of correspondence of styles of learning and teaching (Learning-Teaching_Fit) was determined. Four months after the SLMS tool had been introduced, a link to the anonymous online questionnaire was sent via the e-learning system to the 554 students taking the course. The 257 usable responses were examined using the five variables. A Cronbach's α coefficient was calculated for each of the five factors and it was found (as shown in Table 2) to be reliable ($\alpha \geq 0.60$) for all five factors. The Kaiser-Meyer-Olkin (KMO) test for sampling adequacy indicated an adequate sample size with a high value of 0.93.

Table 2: Factors (with Reliability Coefficients)

Factor	Cronbach's alpha (α)	Mean	Std. Deviation
Performance expectancy (PE _{Ex})	0.784	3.813	0.608
Effort expectancy (E _{fEx})	0.787	4.121	0.623
Attitude towards using technology (Att)	0.812	3.728	0.684
e-Learning Compatibility (EC)	0.806	3.525	0.665
Behavioural intention (BI)	0.776	3.546	0.725

Analysis of data was done in SPSS Version 25: Reliability coefficients by calculating Cronbach's alpha (α); Pearson correlation analysis; Regression analysis for testing Moderation.

RESULTS AND DISCUSSION

For the proposed model the results of the correlation between the four determinants and behavioural intention (BI) are shown in Table 3. E-Learning Compatibility (EC) and Attitude towards using technology (Att) both showed high practically significant relationships with Behavioural intention (BI), explaining 46.1% and 46.0% of the variance respectively. Therefore, students with a

high EC and Att, also have a high intention to use the e-learning tool. Performance expectancy (PEX) also showed a high practically significant relationship with BI, explaining 42.9% of the variance. Therefore, students who believe that using the e-learning tool will help them to improve their performance, intend to use the tool to a high degree. Effort expectancy (EfEx) showed a moderate practically significant relationship with BI, explaining 15.8% of the variance. This is contrary to the findings in Ghana of Attuquayefio and Addo (2014) that EfEx is the dominant determinant of BI, but similar to the findings in South Africa of Benadé and Liebenberg (2017). The contradicting findings might be explained by the different technology tools that were used in the studies. The South African students found the e-learning tool easy to use whereas the Ghanaian students found the mixture of hardware (computers), software (Microsoft Office Tools) and telecommunication (Wi-Fi, e-mail, cellular phones, and internet) tools difficult to use.

Table 3: Pearson Correlation Coefficients with BI

Determinant	Correlation Coefficients	p
e-Learning Compatibility (EC)	0.679	p<0.001
Attitude towards using technology (Att)	0.678	p<0.001
Performance expectancy (PEX)	0.655	p<0.001
Effort expectancy (EfEx)	0.397	p<0.001

For the Learning Styles we scaled the data by using the scores of the four dimensions (Active/Reflective, Sensing/Intuitive, Visual/Verbal, and Sequential/Global). A score of 5a), 7a), 9a) and 11a) was coded with a **1**, a score of 1a), 3a), 1b), 3b) was coded with a **0** and a score of 5b), 7b), 9b) and 11b) was coded **-1**. Table 4 provides a summary of the spread of the 257 students in each dimension. These BCom students have a predominantly balanced preference for both the Active/Reflective and Sequential/Global dimensions. However, they have a stronger preference for the Sensing and Visual categories. This corresponds with the findings of Al-Saffar (2014) in Germany where the business informatics students were predominantly Sensing and Visual learners. These corresponding findings might be explained by the fact that these students belong to Generation Z or the so-called Linksters.

Table 4: Learning Styles (n=257)

Dimensions	Strong (a) = 1	Balanced = 0	Strong (b) = -1
Active(a) / Reflective(b) (AR)	63	158	36
Sensing(a) / Intuitive(b) (SI)	124	106	27
Visual(a) / Verbal(b) (ViVe)	156	89	12
Sequential(a) / Global(b) (SG)	81	153	23

For the lecturer's teaching style we scaled the lecturer's scores of the four dimensions similarly to those of the students. This revealed that the lecturer had a balanced preference in the AR dimension, but strong preferences for the Sensing, Visual and Sequential categories of the SI, ViVe and SG dimensions respectively.

For the Learning-Teaching Fit the following procedure was used: The lecturer's scales were compared with each of the students' scales and coded with a **1** for a fit and **0** for a non-fit. Table 5 shows the scores and the scales of the lecturer in each dimension, as well as the frequencies of fit and non-fit. These BCom students' learning styles fitted well with the lecturer's teaching style in the

AR and ViVe dimensions. They showed a moderate fit in the SI dimension, but a poor fit was found in the SG dimension.

Table 5: Learning-Teaching Fit

Dimensions	Lecturer's score	Lecturer's scale	Fit Frequency	Non-Fit Frequency
Active(a) / Reflective(b) (AR)	3a)	Balanced = 0	158	99
Sensing(a) / Intuitive(b) (SI)	9a)	Strong Sensing = 1	124	133
Visual(a) / Verbal(b) (ViVe)	5a)	Strong Visual = 1	156	101
Sequential(a) / Global(b) (SG)	7a)	Strong Sequential = 1	81	178

When the moderating effect of Learning-Teaching Fit on Behavioural intention was considered, the following occurred. The cross-product of Learning-Teaching Fit and the determinants were calculated and included in the model and in Table 6 the four instances, out of a possible 16, that showed statistical significance on a 10% level are shown.

Table 6: Moderating effect of Learning-Teaching Fit on BI

	Beta coefficient	p
SG_Fit x PEx → BI	-0.985	p<0.001
ViVe_Fit x EfEx → BI	-0.893	p<0.050
AR_Fit x EC → BI	-0.472	0.056
ViVe_Fit x Att → BI	-0.429	0.096

The results in Table 6 show that SG_Fit, ViVe_Fit and AR_Fit have some moderating effect on the relationship between the determinants PEx, EfEx, Att, EC and BI. The results show that the moderating effect in the first two entries in Table 6 was statistical significant on a 5% level. Therefore, the influence of Performance expectancy on Behavioural intention will be moderated by a fit of the students' and lecturer's SG learning-teaching style and the effect will be stronger for students who do not fit with the lecturer's dominant teaching style in the SG dimension, namely strong Sequential. Furthermore, the influence of Effort expectancy on Behavioural intention will be moderated by a fit of the students' and lecturer's ViVe learning-teaching style and the effect will be stronger for students who do not fit with the lecturer's dominant teaching style in the ViVe dimension, namely strong Visual. In Table 6 the remaining two entries do not necessarily show a statistical significant relationship, but there is an indication of a moderating effect to a small extent. The AR_Fit also showed an influence on the relationship between EC and BI. Therefore, the influence of e-Learning Compatibility on Behavioural intention will be moderated by a fit of the students' and lecturer's AR learning-teaching style and the effect will be stronger for students who do not fit with the lecturer's balanced AR teaching style. The model was tested using the entire dataset, applying SEM. Both goodness of fit indices were not acceptable: CFI = 0.355, RMSEA = 0.211 with a 90% confidence interval (CI) of [0.205;0.216].

CONCLUSION AND RECOMMENDATION

One should think that students' learning style and lecturers' teaching style would influence the acceptance of e-learning tools. Researchers have proposed that learning style, teaching style and learning-teaching fit would have an effect on the relationship between determinants of technology acceptance and behavioural intention (Lin et al., 2013; Umrani-Khan & Iyer, 2009). In this study, we proposed and tested the moderating effect of learning-teaching fit on the relationship between determinants of technology acceptance and behavioural intention. It was found that the

Sequential/Global_Fit, Visual/Verbal_Fit and Active/Reflective_Fit show a moderating effect on the relationship between the determinants PEx, EfEx, Att, EC and BI. Since it was found that the Sensing/Intuitive dimension had no moderating effect might indicate that this dimension should be excluded in future models. We found that the proposed model cannot be considered appropriate, since the estimated values of fit indices did not show a good structural model fit to the data in this study. The study will enable improved understanding of the factors that may aid or hinder the adoption of an e-learning tool. Our study emphasised that further research is necessary on the effect of learning styles and teaching styles on the acceptance of e-learning tools.

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DISTRACTION OR OPPORTUNITY? TECHNOLOGIES FOR ADOLESCENT STRESS MANAGEMENT

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ABSTRACT: This is a follow-up to a pilot study that investigated a strategy for dealing with stress symptoms amongst anxious adolescents. In the pilot, technologies were used as a mediating tool in the development of self-regulation skills. Over time, participants reported increased well-being, reduced anxiety, and fewer stress symptoms as a result of these interventions. In this paper, we focus on defining factors that were previously lumped together as “stress symptoms” more clearly and offer a snapshot of what “stress” entails for matric pupils approaching important examinations. To align the study with the life-world of the modern adolescent, the Perceived Stress Scale was adapted into an online instrument using Google Forms and made available to the matric cohort at a school. Alarmingly, less than 1% of all participants showed low perceived stress. The Multidimensional Scale of Perceived Social Support (MSPSS) was also used to explore whether a transactional relationship between individuals can be likened to a transactional “interaction” with a tool or technological mediator. Regarding the nature of social support and the possible role that technologies can play, we found that this needs to be explored further through carefully designed longitudinal research in the future.

Keywords: Adolescents; apps; mobile devices; stress; technologies

INTRODUCTION: DON'T MESS WITH MY STRESS

In an earlier study (Lautenbach & Randell, 2017) we reflected on the experiences of a psychologist working with adolescents who had been referred for stress or anxiety. The aim of the pilot was to invite adolescents to be part of their own wellbeing and stress management, by using technology as a resource to co-regulate their stress management practices. An additional aim was to enable the adolescents to develop valuable life skills for future choices and behaviours. In relation to this, the adolescents' stress symptoms were broadly described, including addictive behaviours that were specifically linked to the use of technologies (De-Sola Gutiérrez, Rodríguez de Fonseca & Rubio, 2016).

When working with trauma and stress, complementary and allied health professionals (including Psychologists, Nurses, Occupational Therapists, Biokineticists, as well as Kinaesthesiologists) and secular or spiritual healers and educators, in order to achieve maximum benefit from treatment interventions, have increasingly embraced results from fields such as neuroscience on the one end of the continuum, and affective social self-regulation, on the other. The key factor in ongoing emotional health and wellbeing, despite rising everyday stress levels, is that people need to be given tools that they can implement themselves, and these tools need to work with the Body as well as the Mind (Baer, 2006; Kabat-Zinn, 2005). Subsequent research suggests that integrative Mind-Body skills such as visualization, mindfulness meditation, and regulation of breathing or other Autonomic Nervous System functions, can reduce the body's stress response of Sympathetic (Fight or Flight) arousal, and even modify physiology, in terms of genes, immune function, anxiety, depression, and risk-taking behaviours (Levine, 2010). We have also noted previously (Lautenbach & Randell, 2017) that adolescents often do not sustain the use of these Mind-Body skills, despite being taught how to

use them. They seem to lose focus, motivation, or interest, if there is no initial period of mediation or “co-regulation” (Culbert, 2017), hence our focus on the technology as potential mediator.

The dilemma facing parents and teachers (who often view the use of technology as distracting, addictive and unhealthy in itself) is that adolescents have expressed opinions that the technology is an essential coping mechanism (Donker, Petrie, Proudfoot, Clarke, Birch & Christensen, 2013; Lautenbach & Randell, 2017). The notable increase in stress symptoms in adolescents, particularly in High School, remains a concern. Most of the participants were initially surprised at the introduction of technology as a mediating tool and were encouraged by the invitational nature of the interventions.

At first they needed the technologies to track, motivate and redirect their practice of these Mind-Body skills. Subsequently, they felt they were more able to integrate and apply these skills without the need for the external co-regulation provided by the researcher and the technologies. By using their internal proprioceptors to sense their moment-by-moment experiences of the “felt sense” (body sensations) (Levine, 2010), the adolescent learned to be aware of, tolerate and regulate their autonomic Nervous System (ANS) response to their stress, and to thus feel better (Lautenbach & Randell, 2017).

In the pilot study, it emerged from the data, that the visual or auditory stimulation, as well as the novelty and intrinsic motivation provided by the technological device, enabled dysregulated adolescents to redirect their attention to their somatic regulation (compare Schaaf, Benevides, Blanche, Brett-Green, Burke, Cohn, Koomar, Lane, Miller, May-Benson, Schoen, Parham & Reynolds, 2010). They eventually learned to do this without needing the device. In other words, this was a transition from co-regulation of their Autonomic Nervous System to self-regulation. “Technologies seem to have acted as suitable mediating tools in the developmental process of learning autonomic self-regulation” (Lautenbach & Randell, 2017). The mediating tools helped to motivate, redirect and refocus them externally, i.e. to co-regulate them.

A limitation in the pilot study, however, was the practice of scaling, i.e. of getting stressed adolescents to self-rate their levels of stress on a scale of one to ten both before and after the interventions. This would of course be highly subjective. An important point to note is that, with their chronic perceived stress levels, adolescents experience heightened nervous system over-arousal physiologically, as *the norm* (Kabat-Zinn, 2015). We are also aware that adolescents sometimes experience meditative or relaxing states to be strange or even “uncomfortable”, in comparison to their usual state of activation (Culbert, 2017). In addition, models for adolescent stress appear to be mostly intuitive adaptations of those created for adults, and there is a considerable need to investigate this in more detail (Culbert, 2017). It would also be appropriate to come up with a model that is more applicable to the young adolescent (not based on models for adult stress) who is a typical high school student, and not part of the clinical population.

In this study, we made use of validated instruments in order to make sense of (and quantify) the variety and range of adolescent stress as presented by matric candidates. The interventions, using a variety of technologies to facilitate mind-body skills, aimed to address stress symptoms in typical matric pupils by giving them tools to track and regulate stress. The idea was to respect the adolescent as the true expert in terms of their stress, and to proactively engage with a non-clinical population who find themselves in a high stakes situation (i.e. the preliminary matric exam). The main aim of the study is, therefore, to formulate a more realistic picture of both adolescent stress in the modern age and the role of technologies in facilitating integration of mind-body strategies for

stress management. We also propose that a new variable be considered within perceived social support, namely, technologies.

INSTRUMENTS FOR MEASURING AND DEFINING ADOLESCENT STRESS

The identification of stress can lead to appropriate responses and timely interventions. There are, however, limited options for the identification of stress in adolescents (White, 2014). Cohen and Williamson (1988) developed the ten-item PSS-10, which measures the degree to which one perceives aspects of one's life as uncontrollable, unpredictable, and overloading. The PSS-10 assesses the amount of stress in an individual's life and not only stress as a response to a specific stressor. In order to align the current study with the life-world of the modern adolescents taking part in the series of interventions, the Perceived Stress Scale (Cohen, Karmarck & Mermelstein, 1983; Cohen & Williamson, 1988) was adapted into an online instrument using Google Forms and made available to the Matric cohort at the school. The original wording and content of the instrument were maintained with the only difference being the online format which allowed participants to complete the survey on computers and mobile devices. The instrument is appropriate for use in situations requiring a brief measure of stress perceptions. This instrument was intended to compare participants' perceived stress related to current, objective events in their lives.

INSTRUMENTS FOR MEASURING PERCEIVED SOCIAL SUPPORT

The Multidimensional Scale of Perceived Social Support (MSPSS) is a subjective tool with strong factorial validity, good internal and re-test reliability, as well as moderate construct validity (Zimet, Dahlem, Zimet, & Farley, 1988). Social support acts as a buffer between stressful life events and symptoms. In the modern age, the question arises as to what exactly contributes towards social support. Could a transactional relationship between individuals be likened to a transactional "interaction" with a tool or technological mediator for example? Shumaker and Brownell (1984, p13) define social support as "an exchange of resources between at least two individuals perceived by the provider or the recipient to be intended to enhance the well-being of the recipient". These resources can naturally have a positive or a negative effect. A most useful notion in the context of this study is provided by Lin (1986, p18) who defines PSS as "perceived or actual instrumental and/or expressive provisions supplied by the community, social networks, and confiding partners". Of course, Lin had no idea back in 1986 that social networks would be expanded to include the host of technological tools and Apps that are available today. Nonetheless, social support may be directly helpful in all circumstances but it may be particularly effective as a buffer during times of stress (Zimet et al., 1988).

We propose in this paper that technological tools and apps can provide coping assistance to adolescents experiencing stress. The tools can help them to change or modify situations, see stressful situations from a different perspective, or even change responses to specific stressors. Tools and Apps for social support can enhance self-esteem and reduce the negative effects of stress in general. The MSPSS clearly differentiates between three sources of social support, namely, family, friends, and significant others. In this study we hope to show that technological tools form a significant part of the "significant other" category. We claim that studies that fail to consider this new source of support may miss important information.

METHODOLOGY: PROACTIVELY ADDRESSING INCREASED STRESS LEVELS

In an attempt to address adolescent stress, we draw on theoretical knowledge of concepts such as development, attachment, co-regulation (Poole-Heller, 2017), self-regulation, neurophysiology (Porges, 2003, 2007; Levine, 2010) and modulation through mobile technologies (Niksirat, Sipasuwanhai, Ahmed, Cheng, & Ren, 2017). Furthermore, using Technology can positively motivate and engage the adolescents' attention in a novel yet comfortable way (Culbert, 2017).

Grade 12 candidates from a single school were invited to learn Mind-Body skills as part of their stress or trauma management in the months leading up to the preliminary examination. The entire matric cohort was initially invited in order to provide suitable baseline data. Twenty-three participants voluntarily came forward and consented to take part in this research after being duly informed about the nature of the research. The necessary parental consent and assent from adolescents under the age of 18 were obtained. Ethical clearance was received from a registered research ethics committee. Participants took part in sessions where they were requested to take part in online assessments aimed at identifying their perceptions and lived experiences of stress. The aim of these assessments was to classify their conceptions of stressful situations using instruments that would not make them feel as if they were part of a clinical process (and possibly enhance any stress they may already be experiencing). For this reason, as explained above, we made use of the PSS-10 and an open ended section to describe pertinent issues on the topic of stress qualitatively. Scores for the PSS-10 were generated by adding the items and reverse-scoring the positive items, namely questions four, five seven and eight (0=4, 1=3, 2=2, 3=1, and 4=0). Higher scores indicated greater perceived stress. A second intervention included the Multidimensional Scale of Perceived Social Support (MSPSS). This was also applied electronically with the assessment being presented using Google Forms.

Once the classification of adolescent stress symptoms and the Perceived Social Support were completed, the researcher introduced participants to Mind-Body skills using technologies as resources to self-regulate and restore balance and wellbeing in their lives (Culbert, 2017; Kabat-Zinn, 2015). These techniques once again included Yoga-type breathing exercises, ANS regulation, postural and haptic system regulators, mindful awareness of their personal body, thoughts, feelings, and meditation (Gomes, 2014; Levine, 2008b, 2010; Van der Kolk & McFarlane, 2012; George, Sackeim, Rush, Marangell, Nahas, Husain, Lisanby, Burt, Goldman & Ballenger, 2000). As in the pilot study, the applications (Apps) or tools included mobile devices running personal health tracking Apps, (e.g. breathing apps or meditation, yoga, and sleep tracking apps) and Websites or YouTube videos using calming music, nature sounds, and guided mindfulness meditation exercises. The adolescents soon indicated a preference for technologies that they felt were more or less helpful in the moment. Breathing exercises were generally introduced first, (eg. Using an App teaching regulated breath exercises, such as “Universal breathing – pranayama free”) then websites or Apps for sleep or mood tracking, (eg. “Sleep better”, “Buddhify” or “Pacifica”) mindfulness awareness exercises, music or meditation, and nature sounds (eg. Youtube videos or podcasts of waterfalls, birdsong, guided nature walks etc.)

FINDINGS AND DISCUSSION

Part of the main aim of this study was to formulate a more realistic picture of adolescent stress in the modern age, along with the role of technologies in facilitating integration of mind-body strategies for stress management. By using technologies and associated Apps we also aimed to extend the notion of social support to include technologies as an integral part of the support role structure for those experiencing stress. To determine this perceived stress, we used the 10 original PSS-10 items combined with a number of open-ended items to invite the participants to elaborate on their perceived stress more broadly.

Table 1: Scoring the PSS-10 with the reverse scoring indicated in yellow (Scores from low to high).

Participants	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	PSS-10 SCORE
12	1	1	2	0	1	1	0	1	0	0	7
7	2	1	4	1	1	1	1	1	1	0	13
4	1	2	3	1	1	2	1	2	2	2	17
11	1	0	3	0	2	3	1	1	4	2	17
20	3	2	3	2	2	2	1	2	1	2	20
18	3	3	3	2	2	2	1	1	3	2	22
13	3	2	3	3	2	3	1	2	2	2	23
15	3	4	4	0	1	2	1	2	3	4	24
9	2	3	4	3	2	3	2	2	1	3	25
14	3	2	3	2	2	3	2	2	3	3	25
23	3	2	4	2	2	3	2	2	1	4	25
1	3	3	3	2	3	3	2	2	2	3	26
8	2	2	4	2	3	3	3	2	3	2	26
17	3	3	4	2	3	3	2	2	1	3	26
2	3	3	3	3	2	3	2	2	3	3	27
6	2	2	3	3	2	4	2	3	3	3	27
16	4	3	3	2	3	3	2	3	1	3	27
5	4	4	4	4	2	3	1	1	2	4	29
21	2	3	4	3	2	4	3	2	2	4	29
3	3	2	4	1	4	3	3	2	4	4	30
22	3	3	4	3	2	4	3	2	2	4	30
19	3	3	4	3	4	4	2	4	3	4	34
10	4	4	4	4	4	4	4	4	4	4	40

Individual scores on the PSS-10 can range from 0 to 40 with higher scores indicating higher perceived stress. Scores ranging from 0-13 would be considered low stress (Green). Scores ranging from 14-26 would be considered moderate stress (Orange). Scores ranging from 27-40 would be considered high perceived stress (Red). Nine out of the 23 initial participants have scored within the high perceived stress range (39%) with another 12 (52%) falling in the moderate perceived stress range. Only two fell within the low perceived stress range. Alarming, less than 1% of all participants show low perceived stress. Stress symptoms amongst matric pupils identified from the open-ended portion of the survey include the following lengthy list, which includes symptoms of depression as well as anxiety and autonomic stress responses. Five indicated sleep disorders with another two waking up in the middle of the night thinking about all the things they have to do; twelve mentioned anxiety, sweating, increased heart rate, and the inability to think clearly (confusion). A tight chest, headache and panic could also indicate a general nervous state. Depression was mentioned directly by three participants, with others referring to feeling overwhelmed, emotional, frightened, frustrated, fatigued, irritable, negative, unhappy and moody with low self-esteem. Disturbingly, one also mentioned thoughts of suicide.

This sense of being overwhelmed is a common theme that arises from the qualitative thematic analysis of the survey data. In fact, 47.8% of participants often felt that they had a lack of control over the important things in their lives. Another possibly serious indictment of our Independent Examination Board (IEB) education system is that 56.5% of the matric participants felt that their difficulties often pile up so high that they appear insurmountable.

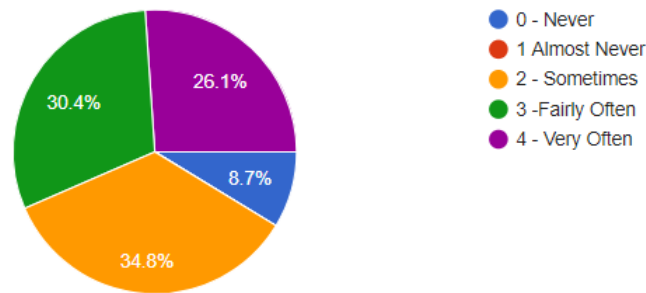


Figure 1: How often participants felt that difficulties were piling up so high that they could not overcome them (Helpless-hopeless feelings)

As expected, the most stressful thoughts of the matric participants over the two weeks prior to the survey included forty mentions of fear and uncertainty over their current academic performance as well as the approaching preliminary examination. Nine others raised insecurities over university entrance next year. Stressful events at home seemed to take a back seat with only five comments. Fear of the response of the parents is mentioned in a few self-berating statements such as *“my parents are going to kill me”*, and *“why am always screwing up?”* Others worried about direction (*“just worries about the future / not having a plan”*) while some were preoccupied with personal challenges (*“is there something wrong with me? Why can’t I stop procrastinating and just get on with it? Why can’t I focus and study?”*)

Participants claimed to “steal” time and avoid tasks between 30 minutes and 4 hours per day. Nine mentioned sleep as their means of escape and only five watched TV. Gym, exercise and sport were an outlet for stress for six participants. The mention of hobbies was minimal (guitar, art and photography) and only one participant could “just relax”. Twenty-five comments were linked to mobile devices and the use of technologies which is by far the greatest way in which they escape overwhelming reality. This can of course create further stress as the tasks mount and time runs out. Technologies and Apps that were mentioned included YouTube and popular series on ShowMax, Netflix and Popcorn Time, Social media (FaceBook, Instagram) video games, music apps (Spotify, Deezer, apple music, Itunes), Communication Apps (WhatsApp, SnapChat), as well as audio books and reading apps (Kindle, Audible).

Despite the recognition of mobile devices as a means of escape most participants had not considered technologies as a resource to help them cope with their perceived stress. In fact, when asked whether they would consider using technologies as an option only two answered positively. Of the other 21 responses, only one did not see himself as a *“tech savvy guy”* and some had simply not considered technologies as an option: *“I didn’t think that technology was an effective way of dealing with the issue”*, *“never really thought about it”* and *“I didn’t know that was an option.”* One participant mentioned that society has already labelled certain aspects of technology as an *“addiction”* while another was willing to try anything that may help to lower stress, even if it had to be technology.

The MSPSS as applied to this relatively homogenous group of participants revealed that all item means fell above the midpoint of 3.5, which could mean that young adolescents perceived themselves to be highly supported by their social environment, which in this case involved meaningful amounts of technological support along with suitable tools and Apps. The promotion of healthy behaviours in adolescents through supportive relationships facilitated by various technological tools is another positive spinoff of this study.

CONCLUSION

This research is a work in progress. A major contribution of this paper is the formulation of a more realistic picture of adolescent stress in the modern age, along with the role of technologies in facilitating integration of mind-body strategies for stress management. By using technologies and associated Apps we have extended the notion of social support to include technologies as an integral part of the support role structure for adolescents experiencing stress.

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AN ACTION RESEARCH PRACTITIONER SUSTAIN THE TEACHING OF TECHNOLOGY EDUCATION THROUGH COMMUNITY ENGAGEMENT

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ABSTRACT: The study report on a three-year journey travelled with Technology Education (TE) teachers with the sole purpose of grounding them with the TE content knowledge. The aim of this study is to provide readers with a fresh perspective on the challenges facing TE in developing countries today, as well as the established skills and intervention strategies necessary to overcome these challenges hence sustaining the teaching of TE. In this study TE has find its way into school environment successfully and effectively through engaging TE teachers with action research approach. Focus group interviews were used to collect data and Technology Education Cascading Theory underpinned the study. The study was conducted with TE teachers as co-researchers from three different secondary schools, at Tshwane West District D15 of Gauteng Province in South Africa. Recommendations to replicate this action research study through community engagement in other developing countries were established.

Keywords: Community engagement; technology education; action research; technology education; Cascaded Theory

INTRODUCTION

Dimri (2018, p. 175) stressed that teacher education and training is very crucial for the sustainable development of the society. Therefore, development of quality education is strongly associated with the issue of teacher education and training. This shows that South African education is experiencing serious challenges in Technology Education (TE) that need immediate attention from all stakeholders. Education has the power to change our world and while the challenges are daunting, collaborated effort on action and research gets results and creates impact (The Fourth Annual Education Handbook, 2013). Changes in the geopolitical and policy environment are taking place in South Africa and abroad, for example the New Development Plan in South Africa, Agenda 2063 at continental level, South Africa's membership of BRICS (Brazil, Russia, India, China and South Africa), and many other opportunities (Makhanya, 2016). The cited scholar is the vice-chancellor and principal of University of South Africa (Unisa, as it is commonly known). Unisa support and encourages its members to embark on Community Engagement activities on a national level.

Action Research (AR) practitioners are modelling Africa out of chronic poverty by sustaining the teaching of TE (Mapotse, 2018), through Community Engagement. The destiny of Africa is in the hands of its own people whom the majority are technologically illiterate and doing their little bit of good. Africans need to move the continent forward by taking it out of the economic quagmire it is in. Human beings and their communities are integral part of Technology Education consciously and/or unconsciously. If teachers are not capacitated to teach TE with confidence and every chance of success, that threatens the community economic thriving. This fact is the cornerstone where sustainability is based. The golden rule is that un- and under- qualified TE teachers should be taken through AR since most never have formal training (Mapotse, 2015). This fact alone will sustain the teaching of Technology henceforth. Sustainable development does not comprise a single universal goal (Elliot, 1994). Who further stressed that sustainability means different things to different people. What is important about this seeking of answers to issues regarding sustainability is that it is

the results of a revolutionary paradigm shift in Technology, Science and development practice (Swanepoel & de Beer, 2011) which is called holism.

IDENTIFYING GAPS IN THE PREVIOUS STUDIES

The scholars in the fields of teacher education have engaged in research targeting variety of aspects on sustainability. For instance, King (2016) took readers through research in, ‘What is Sustainability? Le Grange, Loubser and Le Roux (2014) undertook a study on, ‘Sustainability and Education: a critical discussion’. Le Grange, (2013) have shown interest in, ‘The politics of needs and sustainable education in South Africa’; Jaiwal (2012) successfully investigated, ‘Teacher Education: Issues and their remedies’. Swanepoel and de Beer (2011) focuses their study in, ‘Community Development: Breaking the cycle of poverty’; whereas Wals and Jickling (2002) invested time in unpacking, “Sustainability in higher education: from ...to...meaningful learning.”

The aforementioned scholars belonging to both national and global communities have used some common instruments or similar approaches to gather their data and little has been done in using Action Research (AR) approach to sustain growth in emerging nations. With this study the author, want to attempt to fill that gap by sharing experiences on how the AR practitioners sustain the teaching of Technology Education through Community Engagement since the conventional systems are not able to intervene. The second reason will be that the objective socio-economic conditions of Africa like poor infrastructure for teachers training, low per capita income, poor transport network and low population density drastically reduce access to conventional systems of education. The author will be sharing those Technology Education teachers’ experiences as critical realists using living theory paradigm and underpinning this study through both critical theory and Technology Cascaded Theory. Hence, TE through conventional systems of education will not be replicable and economically viable for the government.

THEORETICAL FRAMEWORK

Theories are needed per study to revel and unpack the research in depth. The theory is looked-for to underpin the whole investigation in this developing study. In most qualitative studies, theory comes at the beginning and provides a lens that shapes what is looked at and the questions asked especially in a transformative research (Creswell, 2014).

Technology Education Cascading Theory – ‘Each One, Teach One’

The researcher as an AR practitioner manages to sustain the teaching of TE through CE in applying Technology Education Cascading Theory. The theory is anchored in the philosophy of ‘each one, teach one’. In year one, the author was an AR practitioner and the three TE teachers from School 1 were the participants’ served as co-researchers. In year two, the author recruited and added a new school to the author’s CE project. In short is that on yearly basis a new school is added to the project. Table 1 unpack the title changes of both the author and the AR participants on yearly bases.

Table 1: Symbolic structure of Technology Education Cascading Theory

Year of Community Engagement	Technology Education teachers as AR participants		
	School 1	School 2	School 3
Year One	3 participants		
Year Two	3 practitioners	2 participants	
Year Three	3 facilitators	2 practitioners	11 participants

This role changes alone makes all who are involved to change their titles annually, for instance, the author in Year One becomes AR practitioner while the TE teachers are participants. In Year Two the author becomes the AR facilitator, School 1 TE teachers becomes AR practitioners while School 2 TE

teachers become participants. Lastly as it is depicted on Table 1, in Year Three the author becomes a participant's observer, TE teachers in School 1 becomes AR facilitators, those in School 2 becomes AR practitioners and the ones in School 3 come to the programme as participants. What is more crucial is that in Year 1 the TE teachers are taken through AR process and in Year 2 they engage their peers from other school with action research (AR) activities. The reason of being the participant observer is to observe how TE teachers present specific TE topic to their colleagues. This training sharpens their TE theme delivery, the author will be certain that if they can present to their colleagues they will be confident to present to their learners. Video recording of the lesson presentations by TE teachers is done in Year 1 and Year 3 on the same topic. The section that ensue outline how TE teachers monitor and measure their progress within the duration of the interaction.

THE ROLE OF TECHNOLOGY EDUCATION IN DEVELOPING COUNTRIES

Technology Education (TE) has the possibility to offer a multitude of benefits for the developing countries from improving education and knowledge sharing, to increase exposure of an innovation to improving the living conditions of the developing countries' residents. TE is new in school curriculum both nationally and internationally (Mapotse, 2013) therefore, teachers need to have basic knowledge of few subjects to be competent to teach it. As Grover (2011) explains that TE is applying maths, science, and other school subject areas, solving practical problems, using knowledge, tools, and skills, action based to increase human potential. If TE teachers could be emancipated they will sustain the teaching thereof. Technology or TE deals with human activities that bring about change and sustainability to enhance the environment, create wealth, produce food and entertainment, and generally get things done. This is in line with the aim of TE, which is to produce engineers, technicians and artisans needed in modern society, and the need to develop a technologically literate population for the modern world (Department of Basic Education, 2011). It is anticipated that if teachers could be capacitated to teach technology with confidence and every chance of success and learner learn TE and engage in solving their community problems technologically poverty will be alleviated.

This study seeks to fill in the gap that AR can sustain the development within a growing country and thus provide readers with platform to model South Africa out of poverty. South Africa can better be model out of marsh economy if its teachers are well equipped to deliver Technology Education to their learners or students. Technology Education (TE) and Action Research (AR) are both the processes. *Action research is a process*, in which participants examine their own educational practice systematically and carefully, uses the techniques of research (Ferrance, 2000). *Technology is a disciplined process* using knowledge, skills and resources to meet human needs and wants by designing, making and evaluating products and processes (HEDCOM, 1996). The goal of engaging in a process is to improve what is being acceptable at present. A definition of a process is well articulated by Johnsey (1997) as a way of going about achieving an end and the separate parts of the process can remain described as process skills. Both TE and AR are having components within their processes that are common to each.

PROBLEM STATEMENT AND RESEARCH QUESTION

Many teachers in the continent on Africa especially in South Africa where the study is located lack the repertoire (and qualification or are underqualified) to teach Technology, as most have been coerced to teach this subject. This calls for the intervention for Technology teachers to realize the needed development in the subject matter to teach it confidently. Considering this, the research question that the study addressed is: How can an Action Research practitioner sustain the teaching of Technology Education through Community Engagement activities?

DATA COLLECTION METHODS

The successful implementation of the Technology curriculum is dependent on teachers having a solidly established personal construct of Technology, equivalent to that of the curriculum (Tholo, Manobe & Lumadi, 2011). South Africa should have been far by now with most cohort of Technology teachers able to deliver the Technology lessons as expected. DBE has since tried to come with interventions to capacitate TE teachers to alleviate the incompetency they suffer. There is a bit of hope to capacitate the teachers since higher education institutions were roped in to conduct CE as part of confronting the problem. In this qualitative study focus group interviews were used as means for data collection and narrative analysis coopted in as outline in the section that ensue.

TEACHERS' VOICES: SUCCESS STORIES OF A DEVELOPING COUNTRY

TE is now ubiquitous in many national curricula of different countries. As a scholar in TE field, the author is not having any qualms of what are the possibilities that TE as a subject can do to encourage learners to follow Engineering and Technology streams when they reach tertiary. Realizing that teachers are in the acumen of TE delivery the author has embarked on CE to emancipate those TE teachers from the quagmire of the lack of didactic and pedagogy content knowledge. After the striking a balance between from being emic to epic AR practitioner through reconnaissance study and applying both Mapotse PEAR model and implement the six weeks emancipation programme for a period of two years, the author involves the participants of School 1 with some interviews. The next section outlines the findings as testimonies that hail from the focus group interviews with TE teachers.

Findings from TE teachers of three secondary schools: – School 1, School 2 and School 3

The focus group interviews were conducted with TE teachers at School 1, School 2 and School 3 Secondary Schools (pseudo names are used to conceal the identity of the schools) and resulted in interesting conversations, which among other things, reinforced that AR was the desired emancipation approach. The TE teachers were more willing to share their experiences and more open to be engaged at any level of future planning. The questions kept the interview facilitator at focus as teachers voiced out their responses. Most of the teachers' responses are highlighted per question as testimonies of the author's CE achievement from AR practices.

- a) Which Technology areas are you now teaching after our AR intervention that you could not teach before?
- *We were totally not teaching our learners drawing because we were not good with that at all since you came and taught us were to start in teaching learners drawing like isometric; 2D; 3D we are now able to teach it;*
 - *We have now seen the resistor and we know its function we can now engage our learners with questions around resistance;*
 - *We can now use a multi-meter to measure in the circuit and electronic components out of the circuit.*
- b) What interaction has AR build among TE teachers within School 1, School 2 and School 3 Secondary School?
- *Before you arrived, each Technology teacher was doing his or her own things at his or her own little corner;*
 - *After your intervention we almost do things together like giving learners same tasks; writing same test; prepare together;*
 - *As we are now sharing everything if one teacher is absent, the other can be able to handle his class.*

- c) What have you learned from AR contact sessions since we were together for more than a year in this journey?
- *Prof we have learned lot of things, among others, on how to present Technology subject properly to the learners;*
 - *We can now teach all the themes in Technology but before you come up with this intervention it was difficult to address some themes;*
 - *There are topics that we totally never teach them to the learners e.g. electrical systems and control: different gates – AND gate and OR gate; resistor colour coding; and their application.*
- d) Is there any setbacks you like to highlight from our AR contact sessions or Technology subject itself?
- *In our Technology subject there is no set back but regarding the contact session we are worried about time;*
 - *The two hours spend for four days in a week bimonthly is not enough to fully capacitate us;*
 - *We wish the contact sessions could be extended into weekends to help learners solve their community problems.*

Recommendations to replicate in other countries

- The AR practitioner should strive to move from emic to epic stance with the participants;
- Analyze the findings from the reconnaissance study, code and categorize the findings into themes;
- The AR practitioner together with the participants as co-researchers should design a plan to prioritize how they are going to tackle the coded themes per cycle of observation, planning, action and reflection;
- Then the team should assess the progress made on their spiral cycle of addressing the themes;
- After member checking the before and after AR intervention should be drawn and the findings can be shared with the public if the all ethical protocol have been observed;
- The team leader should organize the bursaries for the participants to enroll with the ODL HEI for a certificate, diploma or degree depending where they are in their academic standing.

CONCLUSION

Technology Education (TE) teachers were emancipated to teach the subject with confidence and every chance of success through action research spiral cycles. The TE teachers have been emancipated to teach themes of Technology which they normally use to avoid in the past. The empowerment cycle programme with these unqualified and/or underqualified teachers followed the circuit theme as per their work-schedule. A rapport was established with TE teachers as I moved from emic AR researcher to etic AR practitioner. TE teachers take the role of co-researchers in my community engagement project and were elevated to a new level yearly.

This paradigm of 'each one, teach one' has achieved two standing achievements: 1) unlocked TE teachers teaching potential; 2) reveal learners' creativity and innovation in designing technological projects that solve their immediate school problems. In conclusion, I will recommend that the higher education institutions, especially universities, embark on community engagement services with Technology teachers from their nearby schools. This partnership will strengthen the teaching of Technology by TE teachers and its learning thereof by TE learners. In this study, action research with

Technology teachers manages to close the technological pedagogic content knowledge and didactic gap. Africa does not need celebrities, philosophers, political thinkers or religious based organizations to move it towards achieving millennium goals, but Africa needs farsighted scholars, pragmatic academics and ameliorate capacitated Technology Education teachers that translate research into tangible deliverables.

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TECHNOLOGY TEACHERS' INTEGRATION OF TECHNOLOGY-SOCIETY-ENVIRONMENT IN TEACHING-LEARNING ACTIVITIES

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Abstract: The Technology-Society-Environment (TSE) strand in the Technology curriculum in South Africa includes indigenous technology, impact of technology and biases of technology. Consideration of this strand should be ensured in the teaching of Technology. This descriptive case study aimed at investigating how Technology teachers integrate the TSE strand in their teaching activities. There are ongoing debates about Technology teachers' attempts to integrate the TSE strand when planning their teaching activities. Data were collected in the form of document analyses (teachers' work schedules and lesson plans, learners' workbooks and project portfolios). The study targeted two teachers who were purposively selected from different schools at Thuamahashe Circuit, Bohlabela Bohlabela District in Mpumalanga Province to participate in this study. Their planning was looked into and they were also observed. The collected documents were analysed for indications of how the integration of the TSE was done. Content analysis was used in generating codes and patterns to establish in response to the research question. The findings show that these teachers' attempts to integrate the TSE hovered between "not evident at all" and "more evident", meaning that in certain instances they do integrate the TSE.

Keywords: Technology education; technology; technology-society-environment; integration; activities

INTRODUCTION

The TSE strand sets the context for teaching Technology in the classroom (Department of Basic Education [DBE], 2011). Teaching using the TSE strand has the potential to make the curriculum more relevant and learning more meaningful as it provides the opportunity for teachers to engage learners with different real life contexts in constructing knowledge (Naidoo, 2010). Studies concerning the approaches and methodologies for teaching Technology, such as Van Loggerenberg (2000), Reddy, Ankiewicz and De Swardt (2005) and Calado (2018) have been conducted. However, little is known about how Technology teachers integrate the TSE strand as a Curriculum Assessment Policy Statement (CAPS) requirement. The aim of this paper was therefore to establish how Technology teachers integrate the TSE strand in their teaching-learning activities. The research question posed was, *How do Technology teachers integrate the aspects of TSE in the teaching-learning activities?*

LITERATURE REVIEW

Dakers (2006) discussed the various categories of value judgements extensively, which should be considered when designing artefacts. These value judgements have been identified as technical, economical, aesthetical, environmental, moral, spiritual/religious, intellectual and social (Dakers, 2006; Reiss, 2009; Calado, 2018). Dakers (2006, p. 209) further classified these values into two categories, i.e. technical, economical, aesthetical, environmental values as part of the design process; and moral, spiritual/religious and social as part of the society. The categories of values are also distinguished from virtues, which are personal qualities and attitudes which are acquired tendencies to make judgements (Reiss, 2009). In CAPS, these value judgements can be realised in the three aspects of the TSE strand which are discussed next.

Indigenous technology and culture

This aspect has crucial implications for the Technology curriculum as it provides alternative knowledge forms which can enhance the understanding of technology (Gumbo, 2016). Indigenous technology forms part of the concept of technology as a characteristic of humanity as it exposes “how technology is shaped by humans, culture and society (Jones, Buntting, De Vries, 2011; Gumbo, 2018). De Vries (2005) points out that different philosophical traditions have developed their own perspectives on the interactions between humanity and technology. In light of this, attention is drawn to the designers in Technology about the need to integrate indigenous technological perspectives in their designs. According to Onwu and Mosimege (2004), indigenous knowledge supports a combination of traditional knowledge and other knowledge systems such as technology, social, economic and philosophical learning or educational legal and governance systems. Onwu and Mosimege (2004, p. 2) note that indigenous knowledge is essential for existence, survival and adaptation in different environments. Odora Hoppers (2002), locating indigenous knowledge within the arts, argues that this knowledge is not just about woven baskets and handcraft for tourists or traditional dances; rather, it is about identifying and discovering the technologies behind the practices and artefacts. Layton (1996, p. 39) accentuates the integration of the knowledge of previous technological achievements with the cultural variety of technological responses to problems, which is reflective of technology in the real world. Pedagogically and morally, Technology should be viewed as a social and ethical practice (Fleer, 2015, p. 53). Consequently, teachers of Technology should be encouraged to include indigenous technology during their planning and teaching, more so that indigenous knowledge systems is one of the key principles undergirding the CAPS (DBE, 2011).

Impact of technology

This aspect is very important to address the values in technology to reveal the impact which technology has on the way people live and behave in the society (Dakers, 2006; Griffy-Brown, Earp & Rosas, 2018) and how they also impact the development of technology. According to DBE (2011), values, beliefs and traditions shape the way people view and accept technology, and this may have major influence on the use of technological products as technological activity is connected to societal conditions (DBE, 2011; Fleer, 2015). According to Williams and Williams (1996, p. 31), the problems caused by technology do not arise from technology itself but from the conflict which arise when technology is put into use. When products in technology are developed, learners should know what the products’ potential impact are in society, so Technology teachers should foster the integration of this aspect in their planning and teaching.

Biases created by technology

The biases created by technology are with regards to values, attitudes and behaviours. Every society is governed by its culture, beliefs and norms as part of the value system. These exert impact on the choice of the technology products in as far as the product’s appeal to all or restricted to just one sex or to the able-bodied end-users (Dakers, 2006). Thus, technology ends up affecting the costs and benefits of the choices made. Designers who are sensitive to these things will not disregard the implied biases in their designs, hence, they will design with the end-user in mind. Williams and Williams (1996) suggest that tolerance of the range of values and determination to creatively use the tensions between human need values and technological advancement values would represent the path to the resolution of the conflict. In light of this suggestion, teachers should integrate appropriate activities during planning to ensure that learners consider their biases when they develop the technological artefacts in the classroom, society and observe the TSE integration. This aim can be realised if teachers have the knowledge of and are prepared to incorporate the TSE in their planning (Hodson, 2009). There are however challenges that may be encountered when implementing this aspect of Technology, as implementation depends on how the TSE is interpreted

during planning and teaching. In addition, various methods and approaches of teaching Technology can enable the right interpretation. Hodson (2009) fears, though, that some teachers might remain uncommitted to the integration of TSE, perceiving it as diverting from the content.

THEORETICAL FRAMEWORK

This study was framed in knowledge integration (KI). According to Rakevičius and Auzias (2016), KI can be traced back to the business sector where it was/is applied. According to these authors, experts exchange knowledge which can benefit the business organisation with the hybridisation of ideas from different individuals and contexts. In the authors' opinion, knowledge is a flow of information, while information is a flow of messages. In other words, knowledge is created and organised by the flow of information. Knowledge is thus shared and those who share it should show the capability of doing just that. Furthermore, knowledge is mainly categorised into tacit knowledge (knowing 'how'/personal – highly contextual and specialised) and explicit knowledge (knowing 'what'/impersonal – generic and more abstract) (Rakevičius & Auzias, 2016). KI then acts as a catalyst for managing projects which are delivered by multidisciplinary teams. The teams combine their knowledge resources so that they can be innovative and remain competitive. KI helps to transform individual knowledge into collective knowledge and construction thereof especially in solving problems. Due to its noble ideology, KI has made in-routes into the education sector. It builds on decades of empirical studies on teacher and learner learning in K-12 science and engineering classroom (Zitter & Hoeve, 2012). KI transforms the classroom into a hybrid environment where situated theories of learning such as community of practices can thrive based on the social, collective and contextual nature of learning (Zitter & Hoeve, 2012). This theory falls in well with the current study in which the interest of the researchers is on Technology teachers being able to plan and teach in such a way that situates learning within the TSE strand. Teaching should amalgamate the learning experiences and styles of learners as informed by their contexts or environments and demands and problems which need responded to in their own societies.

METHODOLOGY

This is a descriptive and interpretive qualitative case study which studied two teachers in order to obtain their views about their attempts to integrate the TSE in their teaching of Technology. Two Technology teachers (FT1 and MT2 – TF stands for Female Teacher; MT stands for Male Teacher) – coded to protect their identity were purposively selected from different schools at Thulamahashe Circuit, Bohlabela District in Mpumalanga Province. Their purposive selection was based on their responsibility for teaching Technology at Senior Phase in different schools. Their track record about being a culture of planning and teaching, as well as their knowledge of subject matter were also the reasons behind their selection. The schools were selected on the basis of good governance and upholding a culture of good teaching and learning that drew from issues of society and environment. FT1, a female, had seven years teaching experience in Technology and 12 years general teaching experience, held Secondary Teachers Diploma (Natural Science and Technology and Advanced Certificate in Education (Technology), taught Grades 8 and 9 (but only Grade 9 was investigated), had a Technology class of 47 learners in a rural school. MT2, a male, had 13 years teaching experience in Technology and 26 general teaching experience, held Bachelor of Education Honours (Science and Technology), taught Grade 7, had a Technology class of 48 learners in a rural school.

Data were collected through document analysis (teachers' lesson notes – worksheets and/or activity sheets) and observation to identify any evidence about the integration of the TSE. Learners' project portfolios and workbooks were also analysed to obtain data which enhanced the researchers' understanding about the integration of the TSE. For FT1, the content of the lessons was revealed in the analysis (given in table 1) from her work schedule and lessons contained in the teacher's lesson plan file. Fifteen Grade learner project portfolios and 20 workbooks were analysed. A schedule and the teacher's lesson plan file for MT2 were also analysed, as well as 20 Grade 7 learners' project portfolios and 15 workbooks. Ben-Perez's (1990) framework of curriculum material analysis was

adapted for collecting these data. It includes six aspects which are learner image, opportunities for learner development, intended teaching focus, learning styles, interaction between society and technology, and interaction between society and process of curriculum development. These aspects are further unpacked into the subject matter (information, concepts, principles, approach to technology inquiry, relationship to everyday life, image of technology); learner (image of learner – involvement in active learning, opportunities for learner development, materials offering opportunities for cognitive development with specific reference to TSE), intended teaching focus, learning style, learner perceived as able to function in a variety of learning environments); milieu (interaction between society and technology, influences of society on the development of technology is explicitly mentioned in the materials, interaction between society and process of curriculum development, i.e. curriculum material reflects societal needs); teacher (communication of the developers’ consideration of teachers, curriculum material deals explicitly with the developers’ consideration regarding the setting of the context in which curriculum is to be implemented, degree of teacher autonomy, e.g. stating specific objectives, teacher’s role in teaching with respect to material suggesting a central role for teachers as sources of subject matter knowledge, consideration of the teacher’s needs, e.g. curriculum material reflects consideration of opinions and attitudes).

Data collection and analysis were done simultaneously in order to create the opportunity to follow up on gaps in the data and to dig deeper into the meaning of what the teachers had planned. The learner and milieu dimensions focus on planning and preparing Technology activities (for purposes of this study only these dimensions were included). The categories are combined (see tables 1 and 2), which show the six categories on how the planned activities addressed the TSE.

FINDINGS

FT1’s planning and preparation for Technology activities

Table 1: FT1’s planning and preparation for Technology activities (learner and milieu dimensions)

Categories	Not evident at all	Minimally evident	More evident
Learner image		Lesson plans, learners’ workbooks, project portfolio	Work schedule
Opportunities for learner development		Lesson plans, learners’ workbooks, project portfolio	Work schedule
Intended focus of instruction		Lesson plans, learners’ workbooks, project portfolio	Work schedule
Learning style		Lesson plans, learners’ workbooks, project portfolio, work schedule	
Interaction between society and technology	Lesson plans, learners’ workbooks, project portfolio	work schedule	
Interaction between society and process of curriculum development	Lesson plans, learners’ workbooks, project portfolio	work schedule	

The findings from table 1 show that FT1’s work schedule is classified under “more evident” in categories 1 to 3 and “somewhat” in categories 4 to 6. This is an indication that the work schedule contains substantive evidence in categories 1 to 3 and some evidence in categories 4 to 6. The findings reveal that lesson plans, learners’ workbooks and project portfolios are classified under “minimally evident” in categories 1 to 4 and “not evident at all” in categories 5 and 6. This is an indication that the lesson plans, learners’ workbooks and project portfolios contain some evidence

in categories 1 to 4 and no evidence in categories 5 and 6. The work schedule under “more evident” presents the activities which promote learners’ active learning which links concepts to the concrete understanding and acquisition of knowledge across the three themes of the Technology curriculum. The work schedule offers the opportunities for the learners’ cognitive and skills development. It presents the activities which are designed to create a structured and unstructured learning environment as required to enable the different learning styles. This enhances the understanding of Technology knowledge. However, the work schedule “minimally” emphasises the context which shows an influence on the development of technology and its specific development in society. The work schedule “minimally” reflects on the ideological concerns and societal needs in the activities.

The activities in the lesson plans, learners’ project portfolios and workbook were designed to promote learner involvement which “minimally” links the concepts of Technology with concrete understanding and knowledge. These types of activities are for the most part covered in the work schedule. The activities in these documents were “minimally” planned and prepared to create a well-balanced learning environment and to address a shared interest in learners. The activities were planned to promote the learners’ cognitive and skills development as they focused more on the technology knowledge. The interaction between society and technology, the kind of activities outlined in the lesson plans, the learners’ workbooks and project portfolios do not emphasise the influence of the TSE at all. The work schedule “minimally” emphasises the interaction influence of the TSE in certain places. The interaction between society and the process of curriculum development in the lesson plans, learners’ workbooks and project portfolios do not reflect the TSE. The work schedule “minimally” reflects some aspects of the TSE. In conclusion, this teacher has an idea about interpreting the work schedule and enacts it in developing the learners’ activities which are slightly contextualised to the TSE.

MT2’s planning and preparation for Technology activities

Table 2: Teacher 2’s planning and preparation for Technology activities (learner and milieu dimensions)

Categories	Not evident at all	Minimally evident	More evident
Image of learner		Lesson plans, learners’ workbooks, project portfolio,	Work schedule
Opportunities for learner development		Lesson plans, learners’ workbooks	Work schedule, project portfolio
Intended focus of instruction		Lesson plans, learners’ workbooks, project portfolio	work schedule
Learning style		Lesson plans, learners’ workbooks, project portfolio, work schedule	
Interaction between society and technology	Lesson plans, learners’ workbooks, project portfolio,	Work schedule	
Interaction between society and process of curriculum development	Lesson plans, learners’ workbooks, project portfolio,	Work schedule	

The findings from table 2 show that MT2’s work schedule in the learner and milieu dimensions is classified under “more evident” in categories 1 to 3 and “minimally evident” in categories 4 to 6. The project portfolio is classified under “more evident” in category 2. This is an indication that the work schedule contains substantive evidence in categories 1 to 3, as do project portfolios in category 2. The work schedule is also classified under “minimally evident” in categories 5 to 6. This is an indication that the work schedule contains some evidence on categories 4 to 6. The findings further

reveal that lesson plans, learners' workbooks and project portfolios are classified under "minimally evident" in categories 1 to 4 and under "not evident at all" in categories 5 and 6. This is an indication that the lesson plans, the learners' workbooks and project portfolios contain an evidence of categories 1 to 4 and no evidence of categories 5 and 6. The work schedule "more evidently" presents activities that promote learner involvement in active learning which links concepts to concrete understanding, and to acquire knowledge across the three themes of the Technology curriculum. The work schedule and activities in the project portfolios are planned to create the opportunities for learners' cognitive and skills development. The work schedule also presents activities which are designed to create structured and unstructured learning environment as required, to enable different learning styles. This enhances the understanding of Technology knowledge in a holistic manner. However, the work schedule "minimally" emphasises the context which shows some influence on the development of technology and its development in society. The work schedule also "minimally" reflects certain ideological concerns and societal needs in certain activities.

The three documents in categories 1 to 3 present some activities which integrate concepts across the Technology themes. The documents "minimally" offer the opportunities for learners' cognitive and skills development, and "minimally" present the activities which are designed to create a structured and unstructured learning environment as required, enabling different learning styles. MT2 "minimally" prepared activities to suit the different learning environments as required to address different learning styles in understanding technology knowledge holistically. The learners' project portfolios in category 2 offer the activities which give the opportunities for cognitive and skills development through engaging learners in hands-on experiences, and developing knowledge of Technology concepts. MT2's activities regarding the interaction between technology and society do not emphasise the context that could show the influence of aspects of the TSE. The work schedule "minimally" emphasises the context and shows the influence of the TSE in certain places. The interaction between society and the process of curriculum development do not reflect the TSE aspects in the lesson plans and learners' workbooks or project portfolios. The work schedule "minimally" reflects the TSE aspects in certain parts. In conclusion, this teacher has an idea about interpreting the work schedule and enacting to develop learners' activities which are "minimally" contextualised in the TSE.

DISCUSSIONS OF FINDINGS

The lesson plans, learners' workbooks and project portfolios generally appear across the cases to "minimally" promote learner involvement in learning the concepts to concretely understand the categories tabled in the learner and milieu dimensions, thus taking cognizance of Ben-Perez's (1990) framework dimensions. This indicates that the activities presented in these documents contain at least some evidence in the categories. The lesson plans, learners' workbooks and project portfolios "minimally" offer opportunities for learner cognitive development and skills. These can be positively corroborated with the detailed elements from Ben-Perez's (1990) as outlined in the methodology section. However, the work schedule offers opportunities for learner cognitive and skills development "more evidently". The activities in the three documents are presented to address individual or shared interests of learners to no evidence, but they are addressed "more evidently" in the work schedules for the FT1 and MT2. The analysis shows that the teachers' documents were "minimally" designed to create a structured learning environment, did not address the different learning styles which bring the understanding of technology knowledge when integrated with societal needs or the development of technology in society. Literature seems to be less supported in its claims that technology is shaped by humans, culture and society (De Vries, 2005; Jones, Bunting, De Vries, 2011; Gumbo, 2016), hence the need to consider the realities of indigenous technology, impact of technology on society and environment and its biases in the teaching of Technology (Dakers, 2006; Naidoo, 2010). The learner and milieu dimensions on the aspect of interaction between society and technology reveal that lesson plans, learners' workbooks and project portfolios

in these teachers do not emphasise the context that shows the influence of the TSE. However, the work schedules in both categories “minimally” emphasise the context that shows the influence of the TSE in some places. Similarly, the lesson plans, learners’ workbooks and project portfolios in the aspect of interaction between society and the process of curriculum development do not reflect in the ideological concerns of the TSE to address societal needs. The work schedules “minimally” reflect on the ideological concerns of the TSE aspects in certain places. The findings of the learner and the milieu dimensions, in relation to the Technology activities, show that these Technology teachers interpret and enact the work schedule to plan learner activities in Technology out of context. They are more content focused. This means minimal engagement with the aspects of the TSE. The teachers were not clear on how to engage the TSE strand during their curriculum planning in spite of the work schedule outlining such activities. Hodson (2009:) suggests that one of the reasons some teachers are not engaging with the TSE approach in their planning is that they are either not committed to the approach or unsure of it, which might pose a threat in their practice. Hodson (2009) further points out that even if some teachers are committed to the approach they might still not implement it because they lack time to plan lesson activities that integrate content and social concerns. The KI framework finds relevance in the study in the sense that teachers made attempts to consider active and interactive learning, even though this should have been reflected in the learners’ work.

CONCLUSION

This study established that these teachers are not yet fully showing command of integrating the TSE. This creates a need to assist them to interpret and teach the Technology curriculum as it relates to the TSE. Teachers’ development workshops should address this area of need. The teachers’ planning and preparation show their minimal ability to integrate the TSE in their teaching, thus showing the need for this suggested help. There is a need to base Technology teaching on real life, authentic contexts or technological practice outside the school. This study contributes important insights into these teachers’ attempts and ways to plan for and integrate the TSE in their teaching. While the researchers cannot generalise these findings, they think that this phenomenon could be playing out in other contexts as well. Hence, the researchers recommend further research with respect to this issue.

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TUTORS' VIEWS ABOUT THE FACILITATION OF LEARNING THROUGH THE INTEGRATED TUTOR MODEL

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ABSTRACT: The facilitation of learning through tutors is a worldwide approach that is supported by most Open and Distance Learning (ODL) institutions. Learning facilitated through tutoring is considered as a strategy to achieve academic success. The study being reported in this paper explored the views of University of South Africa (UNISA) tutors on the implementation of the Integrated Tutor Model (ITM) used by UNISA to support students. This is not yet a widely researched phenomenon. The study focused on the success factors, challenges and the impact that the ITM has on the tutors' behaviour in terms of tutorial delivery through the ITM. A phenomenological qualitative design was used to collect data from the tutors located within UNISA's Gauteng Region. Data were collected through face-to-face (F2F) interviews. The findings showed some level of success that the ITM enjoys in delivering the tutorials to the students by the tutors; certain challenges that the ITM faces; and the impact it places on the behaviour of the tutors in their delivery of tutorials. These findings help with the understanding of the application of the ITM and information that can help UNISA in strengthening or reviewing the tutor system and the ITM.

Keywords: Integrated tutor model; open distance learning; online education, interaction, facilitation, tutor.

INTRODUCTION

Student support system is regarded as the heartbeat of an Open Distance Learning (ODL) institution (Tait, 2003). Universities around the world have built in tutor support as one of the student support programmes to guide them in engaging in their studies. Recent and rapid developments in Information and Communication Technologies (ICT) and access to internet have made the use of technology a mantra in the teaching and learning contexts. Consequently, it appears that these two educational activities are no more possible without the integration of ICT. Typically, the tutor support service includes elements of face-to-face (F2F) tuition and online to supplement learner progress with self-instructional material. The university may choose to use F2F tutorial support or online or both support strategies and blend F2F and online offering to benefit students – University of South Africa (UNISA), by virtue of being an ODL institution, will however prefer the online mode. It is therefore unsurprising that UNISA is determined to explore the strategies that can improve student support by reducing distance in teaching and learning. Resultantly, in 2012 UNISA introduced the Integrated Tutor Model (ITM) to support its students. Although the model uses both F2F and online tutor support, UNISA cannot avoid the F2F learning delivery mode dictated by the students' circumstances in a developing context like South Africa. Thus, the inception of this model was guided by the UNISA student profile and the principles of equal opportunities and high academic quality (Peters, 2001). The aim of the study was to explore the tutors' views on the use of the ITM in supporting students at UNISA. Tutors' views matter and can contribute to the improvement of the support system, which might in turn assist students to get maximum benefits as intended by the institution.

Students registering with the University are assigned to an online tutor. However, students have an option to get F2F tutorial support by enrolling for this type of support at any UNISA regional service centre within South Africa and Ethiopia (UNISA also services Ethiopia-based students as a special

arrangements in the context of its memorandum of agreement with Ethiopia Ministry of Education). Students are divided into tutorial groups, and each group is taken care of by a tutor who is contracted to the University on a part time basis. The F2F tutorial sessions are conducted on a weekly basis mainly on Saturdays and some on weekdays in the evening once a week for 12 weeks throughout a semester. This schedule is designed in a way that meets the needs of the employed students as well. Students' participation in these sessions is optional, but they are strongly encouraged to participate in order to benefit from the tutor support and share their perspectives and experiences. Online tutorials do not have a fixed tutorial schedule, instead, they are conducted as and when students need support in a particular challenging area of their studies.

FACILITATION OF LEARNING

Facilitation of learning through the ITM

The Commonwealth of Learning (2003, p. 62) explains facilitation of learning as involving how students can develop their own learning path or resolve obstacles to their learning. This requires tutors or facilitators to assist them to develop their own learning skills. According to Ntuli (2016, p. 24), when tutors facilitate learning they should be able to provide students with skills on how to link their existing knowledge to new knowledge in order to make sense of what they are learning and subsequently solve problems. This suggests that providing learning in ODL should be done in a most effective way, otherwise it will be difficult for students to learn. Effective facilitation occurs in a well-resourced environment with participants who are highly motivated and pro-active. Students are encouraged to take more control of their learning process when they learn with and from each other as they identify and implement solutions to challenges, problems or other developmental issues. The tutor manages, organises and intervenes in the learning when necessary (Latakomo Media & Masetlhako Consulting, 2011). Money (2009, p. 2) indicates that "tutoring in ODL is designed to bring an interpersonal element to the learning process, enrich print-based learning through a variety of practical and interactive exercises and foster collaborative learning and support in small groups". The aspect of collaborative learning includes student interaction in the learning. Having said this, it should be noted that tutorage, especially the online one, is a much complex system which is not problem- or challenge-free (Lisewski & Joyce, 2003), thus strengthening the need to gather tutors' views in the context of UNISA.

Interaction in the implementation of the ITM

Tutorials in both media-based and contact-based formats are part of the most effective strategies for creating the learning environments (Money, 2009). The effective facilitation of learning should include interaction at different levels. Interaction is considered as an essential element of distance learning (Hillman, Willis & Gunawardena, 1994; Sher, 2009; Moore & Kearsley, 2012; Zou & Xu, 2015). These cited scholars identify the three types of interaction, i.e. students-content interaction, students-tutor interaction and student-student interaction. Anderson (2011) adds the fourth interaction, i.e. student-interface interaction. It should be noted that interaction could be synchronous (real time) or asynchronous (not real time). Student-content interaction occurs when students take time to study the subject matter by themselves, which can include knowledge, skills and attitude (Swan, 2010). This type of interaction is an amount of time a student spends with the content (Zimmerman, 2012). Tutor-student interaction, according to Zimmerman (2012), is a communication between the tutor and student. The tutor and the student engage in discussions about the content, and each other's expectations around the subject content. Vaughan (2010) asserts that the online contact between the students and teachers increases interaction. The student-student interaction involves communication among students, as well as discussions and engagements about the subject content. This type of interaction may occur through group projects, group assignments and group discussions (Sher, 2009). In student-interface interaction the student engages online and performs some work, e.g. participating in online discussions, downloading the study material and reading the online material about the subject content. These interactions call for

UNISA tutors students to interact at various levels with students through the ITM in order for the learning to take place. Hence, the role played by tutors is crucial in the ITM-based tutorage.

The tutor's role in the implementation of ITM

The tutor's role in facilitating learning at an ODL institution includes the pedagogical, organisational, social and technical roles. The pedagogical role of the tutor requires him/her to guide and support students in the process of learning. It also includes facilitation of online and/or F2F discussions, learning as according to the schedule provided by faculty, and empowering students to develop their own learning skills (Commonwealth of Learning, 2003). Prior to performing the pedagogical activities, the tutor needs to plan, organise and set the objectives and procedures for posting in an online environment or facilitate learning during F2F tutorial class. This is supported by the fact that teaching requires the teacher to choose and construct educational interventions and provide direct instruction when required (Anderson & Dron, 2011) as an organisational responsibility. The tutor performs a social function by communicating with students and making them feel welcomed in the course. This role requires the tutor to create a friendly and comfortable social environment for students to feel that learning is possible (McPherson & Nunes, 2004). This role is called an affective or counseling role (Tait, 2003; UNISA, 2012). Mtsweni and Abdullah (2014) state that tutors perform a technical role as well in the facilitation of learning as students need the technical skills. As a result, tutors should be conversant with the ICT systems to assist and guide the students as they study online. UNISA tutors perform the pedagogical, administrative and affective roles (UNISA, 2012) similar with those described according to Tait (2003).

Access to tutorials support programme

Moore and Kearsley (2012, p. 156) assert: "One special feature of distance education is the capability for an institution to provide access to education to some learners who could otherwise not have it". This includes students in rural areas where connectivity is still a challenge to them. With a growing demand for university education despite the connectivity challenges, higher learning institutions especially in the developing African context have embarked on a blended learning approach to teaching and learning. Universities use both strategies to offer tutorials, i.e. F2F and online. In this way, students have a choice between F2F supports and online, or even consider both modes of support. This is done through the regional learning centres where students can access F2F tutorials in a centre located closer them. The blended learning approach enhances provision, flexibility and promotes active self-directed learning opportunities (Vaughan, 2010). Some students, however, may find it hard to transit from F2F to online provision of learning services, hence UNISA makes provide for both modes. Access to resources includes access to ICT equipment such as computers and internet so that students can access the learning materials and interact with their instructors and other students. But this might not be possible if students cannot operate the resources (McPherson & Nunes, 2004). At least basic computer skills are needed for students who are computer illiterate and may have courses that are offered fully online. Access to tutorials should also be inclusive in terms of students with disabilities, the elderly and those who live in remote and rural areas. Thus, when planning a tutorial programme it is important to consider the student profile.

THEORETICAL FRAMEWORK

The chosen theoretical framework for the study is Salmon's (2000) Five-Stage Model of E-Learning due to the blurred boundary between online learning and e-learning. A combined definition of e-learning and online learning is that it is a structured learning activity which relies on technology especially a computer (e-learning) and needs intranet with its tools and resources (online learning) as the delivery modes for a particular academic purpose, e.g. teaching, learning, assessment and research (Gumbo, 2016). This framework is portrayed in figure 1. The stages include 1) Access and motivation, 2) Online socialisation, 3) Information exchange, 4) Knowledge construction, 5)

Development. The framework includes student activities and antecedent examples of tutor activities (see figure 1). It explains the tutor-tutee activities especially in the context of the ITM in this study.

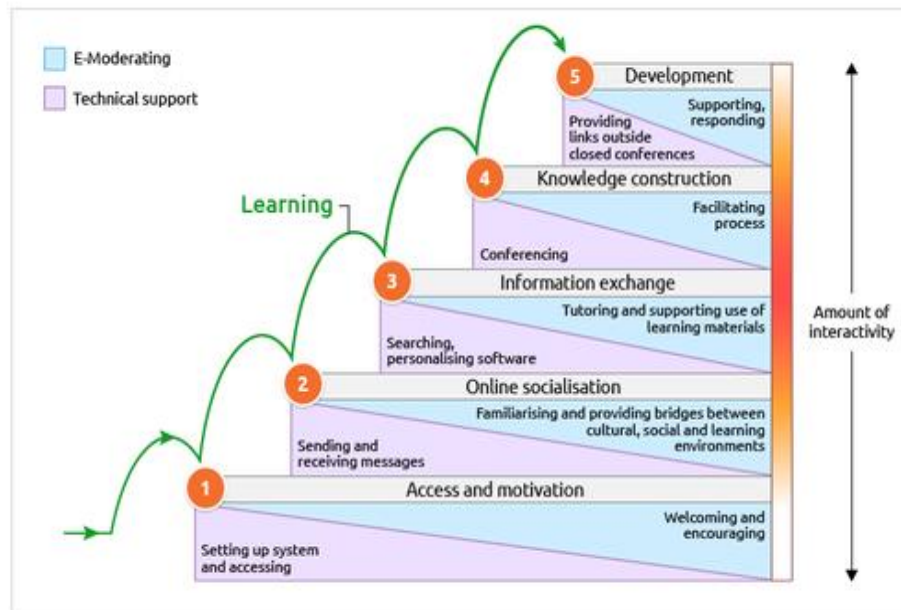


Figure 1: Salmon's Five-Stage E-Learning Model (Retrieved from www.gillysalmon.com/five-stage-model.html)

According to this framework, students should be supported through a structured developmental process if online learning is at all to be successful. It scaffolds for a structured and paced programme of what Salmon (2000) calls e-tivities (online-based activities). The kinds of support and development are offered to students at each stage for them to realise their online learning expertise incrementally. While Lisewski and Joyce (2003) acknowledge the positive side of this framework, they also highlight its negative side using the language "dangers". Among the problems that they identify are, structure and staged timetabling reduce flexibility, rigidity and restriction.

PROBLEM STATEMENT

For many years, UNISA has been supporting students using F2F tutorials as a strategy to increase participation and throughput rate. Recently, UNISA decided to change the strategy of supporting students by implementing the new tutor model called the ITM. However, the model is not devoid of challenges. The main problem relates to students' access and participation. This study sought to explore the following question: *How do tutors experience the ITM in facilitating teaching and learning in an ODL context?* This main question leads to the following sub-questions:

- What are the tutors' views regarding the success factors of the ITM in tutorial classes?
- What are the tutors' views regarding the challenges facing the ITM in tutorial classes?
- How does the ITM impact the tutors' behaviour in terms in their tutorial delivery?

METHODOLOGY

This qualitative study followed the phenomenology design which was found to be relevant as it allowed the researchers to enter the participants' life world, study their experiences as tutors who are involved with the tutoring systems of UNISA and understand the meaning ascribed to their practice as tutors. McMillan and Schumacher (2010, p. 24), indicate that the "aim of a phenomenological approach to research is to transform the lived experiences into a description of their essence, thus allows for reflection and analysis. This design captured the essence of experiences of tutors who are involved in the integrated tutor support system at UNISA.

Based on the above research questions, semi-structured interviews were utilised to collect data from six selected participants. Laforest (2009, p. 1) is of the view that “semi-structured interviews can be used to gather qualitative information”. According to her, interviews of this type are suited to working with small samples. In order to ensure reliability and validity of the instrument, the interview instrument was piloted on two tutors who resembled the participants who were identified for the study. The instrument was adjusted accordingly based on the feedback from the pilot research participants.

Data collected from tutors were firstly organised into codes, patterns and categories, then the themes for presenting the findings were guided by the above research questions to provide answers to them. McMillan and Schumacher (2010, p. 367) define qualitative data analysis as “primarily an inductive process of organizing data into categories and identifying patterns and relationships among the categories”.

FINDINGS

Success factors of the ITM

All tutors who participated in the interviews had three years of F2F and online tutoring experience. According to these tutors, the appointment of qualified tutors to facilitate tutoring through ITM is the first success factor in the programme. The participants expressed their appreciation for the institutional support received as in the following: *Regional administrative support staff is quite helpful such as Tutorial Officers who provide scheduling and constant communication on the changes in the programme; also, the appointment of qualified and determined tutors and staff members is one of the strongest points of ITM.* The support received from some academic staff and regional administrative staff, plus tutor training regional about the facilitation skills was the highlight of the ITM programme. The following views support this finding: *Lecturer assists the tutor by posting a message alerting students of the tutor’s presence on the Learning Management System discussion forum and alerts students of their non-participation and non-responsiveness; and Academic Support Coordinators are of great assistance as well. They are the ones who monitor activities done online by tutors and provide feedback in terms of improvements that could be done. The Academic Support Coordinators also communicate with each and every tutor and tell them about the success and challenges of tutors and also provide recommendations and guidelines.* The second category of success factors in the implementation of ITM is the provision of access to students which includes the provision of computers for learning and internet access, training in basic computer skills in order for students to be fully functional as they engage online. This finding supports the emphasis that literature places on student support (Tait, 2003). This mainly happens by prioritising support to tutors so they can in turn support student. The four interactions explained according to Hillman et al. (1994), Sher (2009), Moore and Kearsley (2012), Vaughan (2010) and Zou and Xu (2015) can then be realisable.

Challenging factors of the ITM

After tutors have been appointed and activated on MyUnisa for the task of F2F or online tutoring, they are expected to start working with students. However, not all of them have access to tutoring materials found on MyUnisa’s Learning Management System (LMS): *Not being able to access material online is a serious challenge in both modes of delivery. Tutors are expected to access tutor material online, however twice already I found that the password does not work and in this case, I used the student’s password to download the material. If you are a F2F tutor, you do not have access to materials that are loaded on myUnisa until the lecturer gives permission to access the material. However, sometimes the lecturer takes his own time and one finds that by the time the lecturer gives permission it’s already late in the semester and the tutor cannot assist students as intended.*

In terms of student participation, it was indicated, *online students do not participate ... the only thing is that they go online, open the material and I suppose they read but they do not respond. Very few of them interact with the tutor.* The tutors experienced a rather low participation rate in online tutorials than F2F participation, hence they were left frustrated. Regarding this, *social interaction is encouraged in the class and in F2F classes the tutor makes sure that it happens, however, in an online environment it's a different ball game altogether because no matter how hard the tutor tries students do not come on board.*

Another challenge was attributed to students not understanding their role and that of a tutor in ODL. Some students wait for tutors to teach them hence students' orientation is crucial in the early weeks after student registration. Lack of internet access for students, lack of feedback from the module lecturers and lack tutor guidance by the module lecturer were enumerated as challenging factors.

The tutors felt that UNISA has a role to play in terms of alerting students about what is expected of them in ODL, as one of them had this to say: *Students need to receive information from the institution about the role of an e-tutor so that they are able to interact with her and get help at all times.*

In terms of this finding, the most important hinderance to tutorage through the ITM is access problems, both for tutors and students. While access is hailed as a special feature of distance (Moore & Kearsley, 2012), this finding shows that UNISA is not doing enough to ensure access, thus the ITM is not really working like an oiled machine in the tutor-tutee working relationships. Although literature makes the roles of tutors and students explicit, even in the context of UNISA (Commonwealth of Learning, 2003; Tait, 2003; Anderson & Dron, 2011; UNISA, 2012), tutors feel that students do not know their roles as yet based on their waiting attitude to be spoon-fed by tutors.

The impact of ITM on tutors' behaviour in their facilitation of learning

Tutors acknowledged that this model has changed the way they facilitate, as they need to be creative and find best practice to tutor online and F2F. A tutor stated: *The support that I get from the administrative staff assisted me to cope and understand that I am dealing with a different kind of group compared to F2F group.* Some tutors also indicated that dealing with students whom they cannot see is a challenge since this requires them to prepare with such students in mind so that they are able to assist them to meet their learning objectives. However, one tutor held a different view and stated thus: *Being involved in F2F with students has actually helped me to facilitate online as if it is F2F. I get to imagine students' existence even if they are not there and that helps me a lot although it is a challenge, but this is one of the strategies that helps me to cope with the changes as a tutor involved in both offerings.*

Tutors are expected to integrate technology in their delivery of F2F tutorials and this requires creative thinking, research and learning from others, for instance, in terms of the need for enhanced communication through MyUnisa, *when you have posted something online, you need to make an announcement so that even those who did not visit the site should be able to see that there is something new on the platform.*

Overall the findings show some success with tutors' working online with students within the ITM. However, the ITM seem not to realise the developmental goals stated in Salmon's (2000) framework. The challenge lies at the baseline, i.e. *access*, which affects everything else that follows in the developmental stages. Based on the students' passiveness, online socialisation, information exchange and knowledge co-construction, student development cannot be realised fully. This seems

to run contradictorily to tutors' provision of support which for some even brings an element of creativity. It would appear, based on what the findings tell, that support is skewed towards tutors than it is to students. But one begins to understand the nature of the challenge when the realities about students' needs still demanding a blended teaching-learning (online and F2F) at UNISA are brought to light. Here, Salmon's framework cannot be implemented as is – oscillating between online and F2F unevaded truth in the context of UNISA. Hence, the standards and rigidity imposed by Salmon's framework, i.e. "danger" (Lisewski & Joyce, 2003) will not make the ITM fit well into the mold of the framework.

CONCLUSION

In exploring the views of tutors about the use of the ITM in facilitating teaching and learning at UNISA, the findings reveal three main aspects, i.e. success factors, challenging factors, and the impact of the ITM on the tutors' behaviour in their facilitation of learning. The success of the ITM can therefore be adjudged partly in terms of what these findings reveal, and within the context of Salmon's Five-Stage E-Learning model – while it benefits students as per the indications in tutors' appreciation of it, it has also attracted some challenges which need attention. Tantamount to tutor training, UNISA should ensure proper orientation of students into the ITM-based project especially with regards to the tutor-tutee roles, and address the access issue effectively. But without access to computers and internet, there will be no interaction between tutors and students, and among students – Salmon's model places high premium on this aspect. This calls for UNISA to increase the computer and internet access for students wherever they are – can be done by introducing mobile stations. This is an area of need in which UNISA can consider collaborating with other institutions for the sake of student access. The limitations of this study lie in the absence of the students' voice or perceptions, which future studies can consider. The contribution of the study in the knowledge field is about the complexities that can be noticed in the ITM juxtaposed against Salmon's framework, given the realities that UNISA students face.

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WHY READING SKILLS IMPACT HIGHLY ON LEARNING TO PROGRAM

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ABSTRACT: This paper provides an explanation for the high impact of reading ability on learning to program. Eye tracking can be used to detect reading skills. Eye-tracking observations in a larger project revealed the risk for students with poor reading skills to fail at introductory programming. We argue that a programming language is a special high-level written language and that using it requires high levels of comprehension, inferencing, selective attention, organising and reflecting. Reading ability will therefore play a significant role in learning to program and lack thereof may be one of the underlying reasons why students struggle to learn to program. Due to the nature of programming languages, reading ability may have a higher impact on learning to program than on learning in other subjects. Improving reading skills may impact positively on learning to program.

Keywords: Human-computer interface; interactive learning environments; postsecondary education; programming and programming languages; teaching/learning strategies

INTRODUCTION

Much of the research in computing education focuses on why students find learning to program difficult, topics causing difficulties and exploring factors that predict student success. A programming language is a high-level written language that relies on the ability to infer meaning between text elements, and link information across textual units, not necessarily in sequential order. This implies that to use a programming language efficiently, would require good reading ability.

This paper relates students' reading ability, as detected through eye tracking, and their performance as novice programmers. The eye-tracking observations were carried out as part of a larger project to investigate the effect of program visualisation on students' learning of programming. While evaluating the usability of a newly developed visualisation tool to support novice programmers, the link between students' gaze patterns, when reading on-screen text, and their performance in the programming course emerged. This article's main contributions are:

- an explanation as to why poor reading skills could affect the ability to learn to program
- empirical evidence that confirms the link between reading ability and learning to program

First presented is a review of related work. Two cycles of direct live observation and eye tracking are then described as well as an analysis of participants' gaze replays and their responses to a questionnaire. Their performance in an introductory programming course is related with the results, offering possible reasons why poor reading skills could have such a big effect on learning to program.

A REVIEW OF RELATED WORK

Reading ability predicts science comprehension and learning (Hall, Maltby, Filik, & Paterson, 2016). Reading is a cognitive-linguistic activity comprising several component skills with decoding and comprehension as the two main components. Decoding is the technical skill to translate written symbols into language. Comprehension refers to constructing meaning from the whole text (Pretorius & Ribbens, 2005). Effective comprehension depends on good decoding skills, but good decoding skills alone are not sufficient for effective comprehension (Bertram, 2006). Comprehension also requires inferencing, i.e. the ability to fill in gaps between text elements and link information across textual units (Rickheit, Schnotz, & Strohner, 1985). "Reading comprehension involves the

construction of a coherent mental representation of the text in the reader's memory" (Kendeou, Van den Broek, Helder and Karlsson, 2014, p. 6). A good reader is a good comprehender (Bertram, 2006).

Other higher-level processes involved in reading include executive function processes such as organising and reflecting on information in working memory while selectively paying attention to specific aspects in the text (Kendeou et al., 2014). Cognitive load theory claims that learning requires information processing in both working memory and long-term memory. Working memory's limited processing capacity is inhibited by intrinsic cognitive load, extraneous cognitive load and germane cognitive load (Sweller, Van Merriënboer, & Paas, 1998; Wouters, Paas, & Merriënboer, 2008).

Children "learn to read" through decoding, but comprehension enables them to "read to learn". By Grades 9 to 12, successful learners has better reading comprehension for complex topics than listening comprehension, in contrast to poor readers. During the post-school phase, highly skilled readers learn more effectively by reading (Matjila & Pretorius, 2004).

Recording eye movements are one of the best methods to study language comprehension processes (Rayner & Pollatsek, 2006). Eye movements during reading consist of fixations (pausing eye movement on a specific area), saccades (the movements between fixations) and regressions (saccades that move backwards in the text). Regressions usually occur when the reader finds the text difficult or does not understand what was read (Rayner & Pollatsek, 2006). Text difficulty, reading skills and characteristics of the writing system all influence fixation and saccade length. The duration of fixations is to a large degree determined by the cognitive workload of linguistic processing (Radach & Kennedy, 2013). More difficult text, typically, causes longer fixations, shorter saccades and more regressions (Rayner, 2009). Beginner, less skilled and dyslexic readers also have longer fixations, shorter saccades and more regressions (Rayner, 2009). Quickly appearing disruptions in eye-movement control could be used to identify syntactic processing difficulties (Frazier and Rayner, 1987; Clifton et al., 2016).

Novice programmers' difficulties can often be linked to a lack of viable mental models for programming (Kieras & Bovair, 1984), such as models of the programming language (i.e., control, data structures and data representation) and the computer, an understanding of the real-world problem domain and program design as well as a model of the actual program (Robins, Rountree & Rountree, 2003). Readers construct a mental model of the content of text (Kendeou et al., 2014; Porion, Aparicio, Megalakaki, Robert, & Baccino, 2016). A good reader should find it easier to create the mental models required in programming.

CONTEXTUALISATION OF THE STUDY AND METHODOLOGY

Background

This exploratory study flows from a larger design-based project that developed and tested an interactive computer-based tool to teach students to trace program code in an introductory C++ programming course. The research was conducted over four semesters during 2012 and 2013 at Unisa – a large open distance and e-learning (ODEL) institution. The size of the student cohort varied between 1200 and 2200 per semester. The tool, called the Drawing Variable Diagrams Tutorial (DVDT), was evaluated for usability and user experience (UX) using eye tracking and a post-test questionnaire. The purpose of the DVDT is to teach students to trace program code by example. In each activity in the tutorial, a program or program segment is traced while each statement is explained on a screen divided into four panels, showing the program code, the computer memory, the program output and an explanation of the statement. Analysis of the results of the eye-tracking study showed that some students displayed reading patterns associated with poor reading skills. Most of these students also failed the module. This was investigated as described below.

Methods

The development and testing of the DVDT was repeated over two cycles (two years). User testing, in a human-computer interaction (HCI) laboratory, was one of the evaluation methods used. Two sets of students – one group from each year – participated in a usability study through eye tracking. The observations were intended to investigate how students would interact with the DVDT on their own.

Data collection: Self-selecting sampling via an e-mail to all students from the course cohort was used to recruit volunteers for observation and eye tracking, while using the DVDT. No reward was offered for participation. Sixteen students participated in the evaluation. The same procedure was followed during both cycles of usability and UX evaluation. A Tobii T120 eye tracker was used to record users' eye movement while performing various tasks on the DVDT. Students were observed one at a time while working through six activities, including a pre-test comprehension test. At the end of the session, participants completed a retrospective comprehension test and an open-ended post-test questionnaire reflecting on the experience. We used the Tobii Studio software to export data in the form of gaze videos (showing the animated fixation paths) and static gaze plots. These are graphical representations of the gaze data superimposed on screen recordings of the students' interaction with the DVDT. A small video, showing the participant's face, is included in the gaze video.

Data analysis: Since each participant followed a different path through the tasks and scrolled differently through the contents of the individual panels, only the gaze videos were analysed. The animated gaze videos were analysed qualitatively. The fixation patterns, gaze paths and regressions were analysed for each participant. The sequence of fixations showing how their eyes moved between the four quadrants of the tutorial screen, the time spent to read a statement or description, and the time spent on each quadrant were analysed for each participant. The intent was to look for insight into the usability and UX of students while using the DVDT. A side effect of this analysis was that their reading ability could be determined from the results. Figure 2 and figure 3 show extracts from the gaze paths of a skilled reader and a participant with reading problems, respectively. The numbers on the fixation circles indicate the sequence of fixations. In figure 3, the fixations jump from panel to panel, while in figure 2, the fixation path follows the words as they are read.

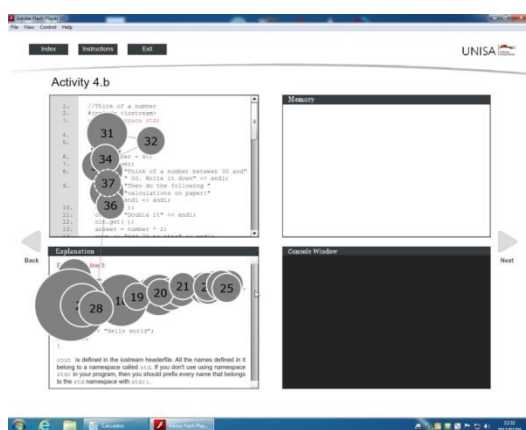


Figure 2. A typical gaze path of a participant with good reading ability

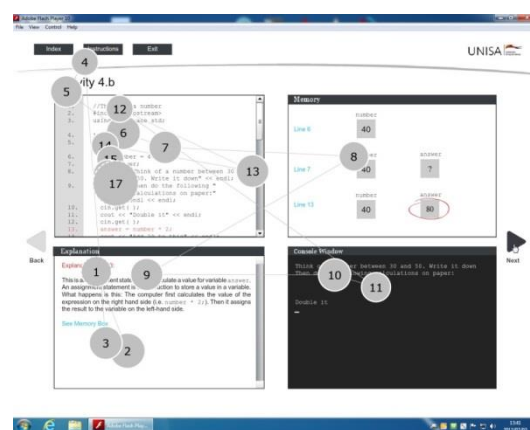


Figure 3. A typical gaze path of a participant with poor reading skills

Analysis of the pre-test and retrospective comprehension test results revealed the level of learning achieved from using the DVDT, while the post-test questionnaire shed light on the students' UX and usability problems.

RESULTS OF THE EYE-TRACKING STUDY

The results of the two cycles are discussed separately, since some changes were made to the DVDT interface after the cycle 1 evaluation.

Cycle 1 results

During the first cycle, ten participants volunteered: two females and eight males, aged between 19 and 33, and speaking eight different home languages. Four had not been registered for the course before, while the others had all been registered before, but they did not all write the examination. All claimed to be computer literate. Four participants passed the final examination, three failed and two did not write the examination. One female whose eyes could not be tracked was excluded. Gaze replays and observation were used to establish how participants experienced the usability of the DVDT. Four main issues were identified, i.e. problems with learning from the tutorial, insufficient instructions on how to use the tutorial, difficulties with navigation through the tutorial and problems with reading skills. For this paper, we are interested in the reading skills of participants.

Four of the participants (P1, P2, P3 and P7) displayed eye movements that indicate good readings skills, reading at a reasonable speed and displaying no obvious reading difficulties while following instructions without hesitation. All these participants passed the examination at the end of the semester. P4, P5, P6, P8 and P9 all displayed eye movements that reflect patterns associated with lack of reading skills, such as erratic eye movements (P4, P5 and P6); rereading text frequently (P5, P8 and P9); short saccades and long fixations (P8 and P9) or using the mouse to guide reading (P6). P4 also seemed puzzled at times. All failed the examination, except P6 and P9, who were absent.

A question in the open-ended post-test questionnaire, completed after the eye tracking and observations in the HCI laboratory, shed light on students' reading skills, namely:

- Would you like to have sound / someone explaining how to do it, while using the tutorial?

Four participants wanted auditory explanations, one would have liked to have it available occasionally and four preferred not to have it. Two of the four participants, who would have liked auditory explanations, failed the examination (P4 and P8), while the other two did not write the examination (P6 and P9). All of them appeared to have inadequate reading skills. Three of the four participants, who preferred no auditory explanations, passed the examination and could read well (P1, P3 and P7). P5 preferred no auditory explanations, but experienced difficulty in comprehending and did not pass the examination. P2 would prefer occasional auditory explanations, although he could read well and passed the examination. The feedback could indicate that those with poorer reading skills requested auditory explanations to compensate for their deficient reading skills.

Table 1 provides a summary of the analysis of the results for the first cycle.

Table 1: Summary of results for first cycle

Participant	Reading skills	Auditory explanations requested	No of times registered for the course	Exam results
P1	Good	No	2	50%
P2	Good	Occasional	1	61%
P3	Good	No	1	64%
P4	Lacking	Yes	1	39%
P5	Lacking	No	5	20%
P6	Lacking	Yes	2	n/a (absent)
P7	Good	No	2	64%
P8	Lacking	Yes	2	10%
P9	Lacking	Yes	1	n/a (absent)

Cycle 2 results

After the first implementation and testing cycle, the DVDT was updated according to the findings of the usability evaluation. In the second implementation cycle, another group of participants was recruited to partake in a similar usability evaluation. Seven participants volunteered: one female and six males, aged between 19 and 31 years and speaking four different home languages. Five were registered for the course for the first time. One of the remaining participants was repeating it for the fifth time, while the other participant did not write the examination during his previous registration. All claimed to be computer literate. Three participants passed the final examination, three failed and one did not write the examination.

Gaze replays and observation were again used to establish how participants experienced the usability of the DVDT, after it had been modified for the second cycle. Focusing on the reading skills, the behaviour and eye movements of P2, P4 and P7 indicated that they can read well and experienced no problems in using the tutorial. They all passed the final examination. P5 also seemed to read well, but struggled to understand the mathematical calculations in activities. He did not write the examination. The poor readers were P1, P3 and P6. They all failed the examination. They all read slowly, and reread text. Both P3 and P6 used the mouse to guide their reading and seemed bemused, while P3 read aloud. P6 also displayed long fixations and erratic saccadic eye movements.

The same questionnaire as in the first cycle was used after the eye-tracking and observation session. Three participants wanted auditory explanations, three preferred not to have it and one would have liked to have had the option. Participants, who could read well, preferred the tutorial without audio (P2, P4, P5 and P7), although P7 recommended a toggle switch for sound to explain more difficult sections. In contrast, three of the four participants, who did not pass, would have liked to have had auditory explanations (P1, P3 and P6). These three participants also struggled with reading.

Among the suggestions to improve the tutorial, there were two that may be related to reading difficulties, namely, issue CDs with explanations for every chapter as well as summaries of certain chapters in the study guide; and add a toggle switch with sound for explanations or help.

Table 2 provides a summary of the analysis of the results for the second cycle.

Table 2: Summary of results for second cycle

Participant	Reading skills	Auditory explanations requested	No of times registered for the course	Exam results
P1	Lacking	Yes	1	30%
P2	Good	No	1	58%
P3	Lacking	Yes	1	19%
P4	Good	No	1	92%
P5	Good	No	5	n/a (absent)
P6	Lacking	Yes	2	14%
P7	Good	No (toggle switch for explanations)	1	89%

DISCUSSION: READING SKILLS AND LEARNING TO PROGRAM

Novices' problems regarding developing viable mental models for programming relate to both the comprehension phase of reading as well as the higher executive functions of inferencing, paying selective attention, and organising and reflecting in working memory. Programming languages may resemble English, but a far higher level of comprehension and inferencing is required to comprehend (read and explain) program code, since higher executive functions need to be used to a far greater extent than when reading conventional text. Program flow is also not sequential, requiring a considerable measure of selective attention, organising and reflecting, all at the same time, in the limited working memory. The eye-tracking study's results show that students, who could read well, passed, while those with poor reading skills, did not pass. Most of those who did not pass, also would have liked auditory explanations included in the tutorial. This can be interpreted as an indication that they lacked the higher levels of comprehension and inferencing required to read a program.

The tight integration of concepts in a programming language indicates a high intrinsic cognitive load (Robins, 2010). Poor reading skills would impose a high cognitive load on working memory, hampering the processes of inferencing, paying selective attention and organising and reflecting, making it difficult to master the subject matter. Students, who struggle to read, will then find it difficult to learn to program.

The part of the brain that processes reading was originally used to locate objects and navigate a terrain (Gous & Roberts, 2014). Reading can be likened to navigation, also involving traversing objects (words and letters) in context (the larger text). Program code too represents an abstract space to be navigated with the same cognitive strategies as used in natural environments (Reddivari & Kotapalli, 2017), since program comprehension is "the process of generating a cognitive map from the program source-code to a set of application domain concepts" (Cox, Fisher, & O'Brien, 2005:93). This, in turn, corresponds to creating a mental model. A strong correlation between students' spatial ability, i.e. their ability to navigate, and their results in programming modules, with much lower correlations between their spatial ability and non-programming modules was found. Students with a low spatial ability also used less effective navigational strategies when attempting to comprehend code (Jones & Burnett, 2007). The relationship between reading and navigational ability explains why students with lower spatial ability struggled more with programming supporting Chmura's (1998) finding that students with poor reading comprehension skills struggle to learn to program. The students in the eye-tracking study, who could not read well, did not pass the examination, bearing this out. This corresponds with other work demonstrating that higher spatial skills allows for better comprehension of science texts, presumably due to the role of spatial skills in creating mental models (Jaeger, R. Taylor, & Wiley, 2016).

CONCLUSION

This paper describes a side-effect from a larger project in which a tool to teach students to trace program code in an introductory programming module was developed and tested. During the qualitative evaluation phase of that study, students were eye tracked in an HCI laboratory to investigate the usability and students' UX of the tool. Analysis of the eye tracking results indicated that most students with poor reading patterns also failed the module. Even though the sample was small, the analysis of the direct live observations and eye tracking confirmed the link between students' reading ability and their ability to learn to program.

The nature of programming languages requiring high levels of inferencing, selective attention, organisation and reflecting, to read and understand program code, explains the link between reading ability and programming. Programming languages' high intrinsic cognitive load also taxes the processing capacity of working memory, making it more difficult for poor readers to learn to program. The relationship between the area in the brain – where both reading is processed and navigational ability is seated – and comprehending program code supports our argument that poor reading skills can make it more difficult to learn to program. It also raises the question whether poor reading skills have a larger effect on success in programming modules than in other modules.

The fact that our participants, who lacked good reading skills, as identified during the eye tracking, failed the introductory programming module, confirms that poor reading skills can be associated with students' ability to learn to program. Programming lecturers need to take cognisance of this and, in their remedial work with struggling students, they will have to acknowledge that the problem may be related to students' reading skills. If the reading skills of these students can be improved, it may well assist them in learning to program and improve their overall academic performance.

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SENIOR PHASE TECHNOLOGY TEACHERS' PROFESSIONAL DEVELOPMENT AND IMPLEMENTATION NEEDS: A CASE STUDY

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ABSTRACT: Technology Education holds a novel opportunity to capacitate citizens with technological literacy and 21st century skills needed in the global economy. The South African Department of Basic Education advocates for the infusion of indigenous knowledge in the General Education and Training Band for Technology Education. Technology teachers are therefore strategically positioned to ensure that the department achieve this goal. However, literature postulates a number of challenges experienced by Technology teachers regarding the infusion of indigenous knowledge in the Technology curriculum. This is a design based study, in which various cycles of presenting a short learning programme on indigenous knowledge to Technology teachers were researched. This paper focuses on Cycle 1, highlighting the affordances (and challenges) of the infusion of indigenous knowledge in the Technology curriculum. In this paper we report on the challenges experienced by teachers regarding the infusion of indigenous knowledge in their classes. Some of these challenges includes negative attitudes of Technology teachers about indigenous knowledge in their classrooms and lack of appropriate pedagogy for such an epistemological border-crossing. Continuous Professional Teacher Development and the use of alternative teaching approaches to infuse indigenous knowledge into the Technology curriculum are recommended as possible strategies in order to unravel some of the identified challenges.

Keywords: Technology education; indigenous knowledge; teacher professional development; Cultural Historical Activity Theory (CHAT)

INTRODUCTION

Technology Education was introduced as a school subject in South Africa as a result of post-Apartheid curriculum reform to respond to the technical needs of the global economy (Stevens, 2006). The rationale for its introduction, according to the South African Department of Basic Education (DBE), was to give rise to engineers, technicians, and artisans required in present-day society (Department of Basic Education, 2011). The DBE Curriculum and Assessment Policy Statement (CAPS) posits that the subject stimulates learners to be innovative and develops their creative and critical thinking skills. The document also states that technology education teaches learners to manage time and material resources effectively, provides opportunities for collaborative learning and nurtures teamwork (Department of Basic Education, 2011). However, since its implementation, technology education has undergone numerous reforms. Currently, it is taught in intermediate, senior and FET phases of the South African school curriculum to prepare learners for the world of work. The technology education curriculum also expanded to include South Africa's wealth of indigenous knowledge (IK) (Cronje, 2015). Indigenous knowledge is an accumulation of knowledge and experiences that is embedded into culture and history (Dei, 2000). It is a dynamic combination of technology, philosophy, science, economy and governance systems derived from intimate relationships with specific cultural environments (Odora-Hoppers, 2001; Semali & Kincheloe, 1999).

The DBE strongly encourages the inclusion of IK contending that "wherever applicable, learners should be made aware of different coexisting knowledge systems. They should learn how indigenous cultures

have used specific materials and processes to satisfy needs, and become aware of indigenous intellectual property rights” (Department of Basic Education, 2011, p. 11). The infusion of IK in the technology education curriculum has the potential to make teaching more relevant to the lived and cultural experiences of learners (Muchenje & Pedzisai, 2013). However, implementation is mired with a multitude of challenges.

Challenges of integrating IK into senior phase technology education include lack of teacher pedagogical content knowledge, inadequate teacher training and professional development, lack of literature on IK and top down curriculum development and implementation (De Beer & van Wyk, 2011; Pool, Reitsma & Mentz, 2013; Potgieter, 2004, 2013; Teis, 2014). According to Shulman (2004) pedagogical content knowledge (PCK) is a blend of content knowledge and pedagogical knowledge that fosters deeper understanding of the nature and processes of the technology. It requires synergy of multiple knowledges and skills in the classroom. The authors contend that an additional skill required for effective technology education is epistemological border crossing, which requires teachers to understand the epistemological, social, historical and cultural contexts of their learners, as well as a sound understanding of the tenets of respectively technology and indigenous knowledge (Cronje, 2015). To meet some of these challenges, a short learning programme was designed to offer technology teachers the needed PCK and teaching strategies for integrating IK into their classrooms.

THE INTERVENTION

The North-West University conceptualized a three-day short learning programme (SLP) in IK for technology classrooms. The NQF Level 6 (16 credit) course was presented to senior phase technology teachers in the Namakwa district of the Northern Cape Province. The Namakwa district is home to indigenous knowledge holders that possess an accumulated body of knowledge and skills that are embedded in their close relationship with this geographical location and natural environment (Mapara, 2009; Odora Hoppers, 2002). The SLP was designed to enable educators to integrate local IK as a learning outcome in the technology curriculum through classroom based activities and teaching strategies. Completion of the course required teachers to submit a portfolio demonstrating the application of what they learned into their classrooms.

The intervention utilised a design process approach to expose technology teachers to innovative teaching strategies, PCK and IK. Theoretically, the design process is an experience-based programme that engages learner curiosity and creativity to meet the needs of humanity (Pudi, 2007). The process is embedded in the technology curriculum in intermediate, senior and FET phases encompassing problem solving and design, resources and materials problem solving, technical systems, resources and materials, criteria and constraints, optimization and trade-offs and many other human topics (Dugger & Naik, 2001). The technology subject demands that teachers integrate theory and practice to engage learners and foster 21st century skills. Integrating theory and practice requires technology teachers to employ the design process as the foundation for technology teaching.

The design process is the “core of the practice of technology” (Franssen, Lokhorst & Van de Poel, 2013). The process includes a configuration of steps and criteria for solving an identified problem (De Vries, 2012). The steps can be linear or cyclical. Figure 1 is a representation of the six-step cyclical design process modelled in the intervention.

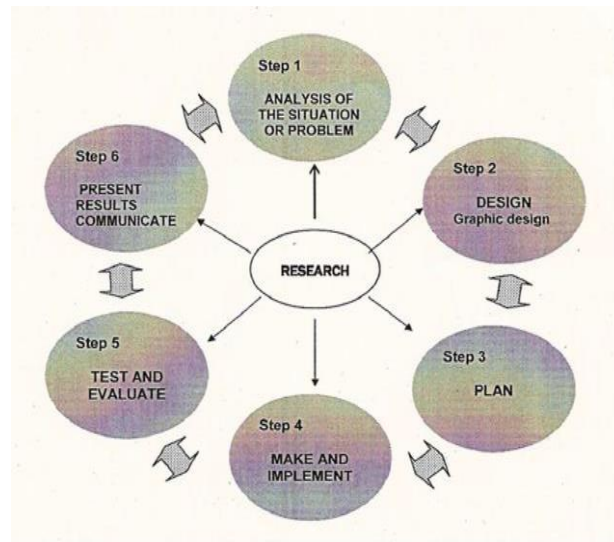


Figure 1: Six Steps Cyclic Representation of the Design Process (Combrinck & Reitsma, 2004, p. 15)

Criteria or requirements are embedded in each step, therefore following the steps generates a conceptual solution to the problem (2016 Online). Senior phase technology learners are required to follow the process, create a solution and implement the solution. The Department of Basic Education (2011) coined the process as IDMEC (Investigate, Design, Make, Evaluate and Communicate). Learners follow these steps to identify problems and generate answers to the identified problems.

THEORETICAL FRAMEWORK AND RESEARCH LENS

Theoretical framework

Social-constructivism forms the theoretical framework of this intervention. During the SLP the focus was on scaffolding teachers' learning across the zone of proximal teacher development (ZPTD) (Warford, 2011). Warford (2011) provided a specific gaze on the well-known Vygotsky (1986) construct of the zone of proximal development, by focusing on stages that should comprise the scaffolding of teacher's learning.

Cultural Historical Activity Theory (CHAT) as research lens

This research draws on Engeström's (1987) formulation of the third generation cultural historical activity theory (CHAT) to understand the challenges of senior phase technology teachers regarding integrating IK into their classrooms. CHAT emerged from a Vygotskian school of thought. Engeström theorizes that all human activity is anchored in the interaction between seven elements: subjects, objects, tools, outcomes, communities, division of labour and rules (Yamagata-Lynch & Haudenschild, 2006). A goal or expected outcome drives the activity system and mediates interaction between individuals, groups and collectives (Anthony, 2012). CHAT emphasizes the activity system embedded in learning and human development (Forbes, Madeira, Davis & Slotta, 2009). According to Foot (2014) individuals are shaped by their cultural historical trajectories, values and resources. CHAT considers that a learner does not enter the technology classroom as tabula rasa. Instead, learners represent the cultural and historical knowledge communities. Connecting their social cultural realities to the curriculum can provide unique opportunities to engage learners with the technology curriculum.

Theoretically, CHAT considers the social constructivist nature of learning that holds that knowledge creation is a social and cultural human endeavour of interpretation and understanding (Adams, 2006;

Amineh & Davatgari, 2015; Andrews, 2012). Social constructivism not only aligns with the communal nature of indigenous knowledge, but also fosters a learner-centered learning environment.

METHODOLOGY

This generic qualitative research study was designed to investigate the challenges technology teachers face regarding implementing professional development into their senior phase technology education classrooms. The research questions guiding the study were: (1) What are the professional development needs of senior phase technology teachers? (2) What challenges do they face when applying the newly acquired knowledge and skills in their classrooms? Eight senior phase technology teachers who attended the SLP volunteered to participate in this research. At the conclusion of the SLP, teachers were asked to reflect on their classrooms and the intervention on a semi-structured/open ended questionnaire. Prior to the SLP, a panel of experts ensured the construct validity of the semi-structured questionnaire. A convenience sampling method was used as all teachers attending the course participated. Descriptive coding as defined by Saldaña (2009) was used to organize the data into categories and themes to answer the first research question.

The authors used third generation Cultural Historical Activity Theory (CHAT) as a research lens to explore the challenges experienced by senior phase technology teachers when applying intervention knowledge and skills into their classrooms. According to Taylor (2014), "CHAT is appealing because, like other approaches embedded in a dialectical tradition, it aims to understand how to create the conditions for full human development" (p. 96).

FINDINGS

During the SLP, technology teachers were engaged in the application of the steps of the technology design process and cooperative learning strategies, while navigating the epistemological border crossing between indigenous knowledge and the more 'western' technology curriculum. We highlight four provisional themes that emerged from the data. (This research is still underway). Findings revealed the training needs of senior phase technology teachers regarding integrating indigenous knowledge into their technology classrooms.

Theme 1: Teachers benefited from the SLP, and also indicated the need for continuous in-service teacher professional development

Technology teachers indicated that in-service training is necessary for integrating indigenous knowledge into the technology classroom. While the DBE encourages teachers to infuse indigenous knowledge into their classrooms, the CAPS document does not specify how to accomplish the task (De Beer, 2016). The lack of training left many teachers frustrated with the task of integrating indigenous knowledge. Therefore teachers welcomed this SLP, and indicated that it greatly assisted them in their professional development to engage in such epistemological border-crossing in the classroom. They also suggested that more such interventions are needed.

In responding to the in-service training needs of technology teachers, one participant reported:

I really enjoyed the course and I really feel capacitated, I believe if done correctly the design process included in the three task type for technology teaching makes it easier for learners to engage and draw from their parents...

It was really fantastic, the facilitators made their presentation lively and relevant...

These findings are consistent with the study conducted by Cronje et al. (2015), who reports an increase in interest and capacity of teachers when attending professional teacher development opportunities. We are reminded by the Bernstein study (2011) that indicated that once-off workshops

are not sufficient, and that longitudinal teacher professional development (within communities of practice) are needed. This was echoed by the participants in this study.

Theme 2: The need for continuous PCK development

De Vries (2005) argues that effective teaching of technology requires specific knowledge, skills and awareness of the technological world (pp. 9). This knowledge must be aligned with appropriate teaching strategies or pedagogies (Cronje, 2015). Teachers' lack of pedagogical content knowledge (PCK) can hinder effective instruction. Participant teachers confessed their lack of technology pedagogical content knowledge. One participant in the study reported:

You know I have been avoiding to begin my lessons with case studies as I considered them a waste of time, now I realise their importance...

I see now that that can be used as a base to assist in the resource task...

When my learners do PAT [Practical Assessment Task], they can see how the content is aligned....

Theme 3: The need for structured support

The Northern Cape is South Africa's most sparsely populated province. The Namakwa district is comprised of rural schools located an average of 200 kilometres apart. This distance and limited internet connectivity confounded the establishment of a technology teachers' community of practice. Lave and Wegner (1991) define a community of practice as a group of people with common interests coming together to share knowledge and improve their practice. During the SLP, teachers commented on the lack of connection, and emphasized the need for support, in order to apply the professional development training in their classrooms. One of the teachers in the Northern Cape stated:

I sometimes feel isolated in my classroom, as I do not have other teachers who can mentor me. Sometimes you just need a colleague who can critique your lessons.

Technology teachers indicated a need for school level support. Two thirds of the teachers indicated that they were not qualified to teach the subject area. They stated that many schools did not have a qualified technology teacher, instead teachers of other subject areas were recruited to teach technology. In addition to the lack of specialized training and content knowledge, teachers reported that the school schedule did not allow time for reflection on classroom practice. Teachers reported being overwhelmed with CAPS requirements that demand the majority of their focus and time. Technology teachers indicated that more often their focus in on completing the work prescribed for the term and little time is afforded for infusing indigenous knowledge. Two of eight participants submitted the portfolio required to complete the course. This could indicate the need for supportive follow-up interventions and guidance on how to complete the portfolio tasks.

Theme 4: Transfer to the classroom: a mixed-bag

One of the Technology teachers submitted an excellent portfolio, whereas the second portfolio provided evidence of chalk-and-talk approaches, and 'lip-service' to indigenous knowledge, despite the intervention. From the latter portfolio, it was clear that systemic factors (e.g. timeframes provided by the Department of Education) often result in teachers abandoning inquiry approaches favouring the technology design process, in favour of transmission-mode teaching.

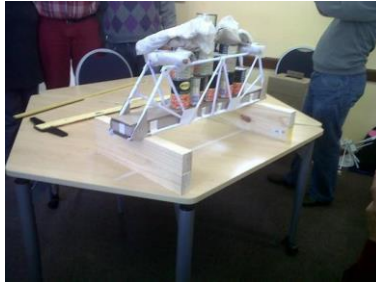


Figure 2. The better portfolio, in which the teacher provides evidence of learners engaging in the technology design process. Here the learners tested the strength of their constructed bridge

DISCUSSION

Based on the aforementioned themes, senior phase technology teachers recognized their need for in-service training, pedagogical content knowledge development and structured support to effectively implement appropriate teaching strategies and integrate indigenous knowledge in their technology classrooms. The findings illustrate that technology teachers face challenges transferring knowledge gained in the short learning programme to their classrooms.

CHAT is useful for understanding the tensions between and among activity systems (Rogoff, 1990; de Beer & Mentz, 2017). In the two activity systems in Figure 3 (the SLP on the left, and transfer in the classroom on the right), one can clearly see that the two objects of the activity systems are not aligned. The object during the SLP was to address the technology design process as a vehicle for epistemological border crossing. Unfortunately the object that materialised in some of the classrooms (with exceptions- as indicated in Theme 4) were the traditional 'chalk and talk' process. Such 'conflict' between the objects for interdependent activity systems are referred to as the 'contradiction of control' (McNeil, 2013; Mentz & de Beer, 2017). This might hinder technology teachers from implementing professional learning in their technology classrooms.

In Figure 3, the triangle on the left represents the activity system of the SLP. Senior phase technology teachers are the subjects and the object is epistemological border crossing where teachers infuse indigenous knowledge into the technology design process. , Tools include indigenous knowledge, cooperative learning and practical hands-on activities (e.g. building bridges). These are tools that foster achievement of the object within the community or group the technology teachers are a part of, which is the short course intervention community in this case. The division of labour refers to how tasks and responsibilities are defined and shared among participants engaging in the activities. In this case, facilitators were responsible for modelling the design process, cooperative learning strategies and reflection during the short course to teach pedagogical content knowledge, encourage epistemological border crossing and influence integration of IK in technology classrooms. Technology teachers were responsible for learning during the course and applying strategies and knowledge in their classrooms. The activity system was governed by the rules of the CAPS curriculum, steps of the design process and elements of cooperative learning.

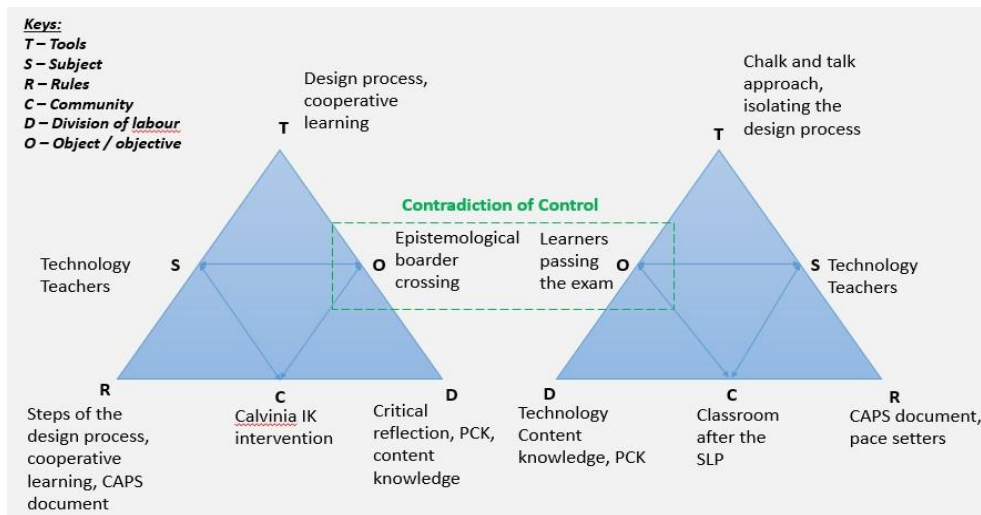


Figure 3: CHAT Interpretation of the findings (Based on de Beer & Mentz, 2017)

The triangle on the right represents the activity system in senior phase technology classrooms. At the beginning of the short learning programme, the technology teachers (subjects) indicated that they did not know how to infuse indigenous knowledge into their classrooms. They indicated that very little of the application design process is taking place in their classroom hence they resort to ‘chalk-and-talk’ approaches. Teachers focus on adhering to the rules (CAPS document), in an attempt to complete the prescribed syllabus and prepare their learners to pass the exams. The rules of the system define the division of labour. Teachers are responsible for manipulating tools to deliver the curriculum to learners and prepare them to pass assessments. Only two portfolios were received when this paper was written, and the two portfolios were very different. One portfolio provided good evidence of transfer to the classroom, whereas the other portfolio indicated that the teacher did not change his pedagogy whatsoever after the SLP.

Technology teachers are operating in both activity systems that conflict with each other. The activity system on the left occurred within the structured intervention environment and the system on the left represents the reality of the technology classroom. The CAPS document and assessment are rules in both systems that influence other elements of the activity system. However, the CAPS curriculum encourages use of the design process and integration of IK, but they do so without providing necessary support to ensure the implementation of appropriate strategies and knowledge in the technology classroom. The role of technology teachers in creating a technically literate citizenry conflicts with the school structure seeking to control learners. The design process has potential to meet the DBE technology education goals, however the outcome is not as predictable as chalk and talk methods that technology teachers are more comfortable with. McNeil (2013) defines the conflict between educational goals and social goals as a contradiction of control.

RECOMMENDATIONS AND CONCLUSION

Technology education is a vital component of South Africa’s social, cultural and educational transformation. Findings in this study offer insights into the challenges faced by senior phase technology teachers regarding implementing professional development knowledge and skills into their classrooms. The results demonstrate that in technology classrooms, teachers face curricular demands that often erode the knowledge they gained in the professional development course. Based on the findings of this study, it is recommended that professional development include continuous longitudinal support for teachers. Follow-up visits and structured

support may ensure sustainability. It is imperative that technology teachers receive specific training in the subject area to foster PCK and effective integration of IK into technology classrooms. The lack of appropriate training disadvantages teachers as they resort to ineffective chalk and talk methods to teach a curriculum that they do not understand. The CAPS curriculum places explicit pressure on teachers to meet curriculum benchmarks and prepare learners to pass assessments. Systemic challenges regarding preparation and reflection time place pressure on teachers to focus on systemic problems also put more pressure on teachers to focus only on preparing learners to pass their examination rather than cooperating theory and practise demanded by the subject technology.

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ENGAGEMENT OF STUDENTS IN A GAMIFIED PROGRAMMING LEARNING ENVIRONMENT

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ABSTRACT: The usage of gamified systems in educational settings is gaining momentum and is predominantly used for the purpose of promoting motivation and engagement in learning. Prior research on gamification indicates that the introduction of gamified systems lead to higher levels of student engagement. However, according to various scholars, the knowledge base connecting gamification to theoretical principles is thin and the empirical research on gamification founded on theoretical principles is lacking. To help overcome the lack of theoretical support, this study develops a research model that predicts the engagement of students in a gamified programming learning system by drawing on two theories namely Self-Determination Theory and Mechanic-Dynamics-Aesthetics Theory. The population of the study consisted of 192 second year Information Technology students enrolled at the Central University of Technology in the Free State. An online questionnaire was used to collect data from students. The results indicate that various game dynamics namely rewards, self-expression and competition should be implemented in a gamified learning system in order to satisfy the needs of students for autonomy, competence, relatedness and enjoyment. The study indicated that if these needs of student are met, it will lead to higher levels of student engagement in a gamified learning environment. The results of this study could assist instructors at higher education institutions to incorporate gamified learning environments in their teaching practices.

Keywords: Gamification; game dynamics; engagement; higher education

INTRODUCTION

As a reasonably novel paradigm to engage users, gamification has been embraced as a strategy to influence and motivate people to participate in marketing, training, education, networking, and health related activities (Kankanhalli, Taher, Cavusoglu, & Kim, 2012). Gamification, refers to the usage of game elements, such as game mechanics and design techniques, to augment non-game contexts and as a result motivate and engage users (Deterding, Dixon, Khaled, & Nacke, 2011; Simoes, Redondo, & Vilas, 2013). The potential that gamification has to positively impact user engagement, performance and productivity has been discussed by various researchers (Kankanhalli et al., 2012, Simoes et al., 2013). Despite the growing interest in gamification, few studies have theoretically explained how and why adopting game elements influences user engagement, and limited empirical evidence regarding real impact is available (Seaborn & Fels, 2015). Moreover, in an educational context, research are being continuously developed with the objective of unravelling the factors that would promote the engagement of students in learning activities (Da Rocha Seixas, Gomes, & De Melo Filho, 2016).

To fill this gap, this study aims to develop a theoretical model in order to predict the engagement of students in a gamified programming learning environment. The main research question of the study is: How do game design elements work to engage students in a gamified learning environment? The paper is structured to present the theoretical model and hypotheses. Subsequently, the methods is discussed followed by the results, discussions and conclusions.

THEORETICAL MODEL AND HYPOTHESES

Two theories have been employed in this study to investigate the impact of game design elements on user engagement: Self-Determination Theory (SDT) to theorize what factors determine an individual's engagement and Mechanics-Dynamics-Aesthetics Theory (MDAT) to theorize how game elements increases users' intrinsic motivation.

The first theory used for the development of the theoretical model for the study, SDT is an extensively studied theory of human motivation and postulates that people engage more in an activity when they are intrinsically motivated (Ryan & Deci, 2000). According to SDT, conditions supporting individuals' experience of competence, autonomy, and relatedness stimulate their intrinsic motivation, which in turn increases their levels of engagement in activities (Liu, Santhanam, & Webster, 2017). Furthermore, SDT is rooted in socio-psychology and describes why people engage more in a certain activity when they feel enjoyment. Since the main purpose of gamification is to increase the engagement of users, SDT is relevant for understanding user's engagement in gamified systems (Suh, Wagner, & Liu, 2015). SDT suggests that individuals' intrinsic motivation for a specific activity can be predicted by competence, autonomy and relatedness. Autonomy refers to a sense of choice or willingness when doing a task, in other words having a sense of free will when doing something or acting out of own interest and value (Ryan, Rigby, & Przybylski, 2006). Competence involves the desire to be effective in an environment or master the environment (Ryan et al., 2006). Relatedness refers to the desire to interact with others and is experienced when a person feels connected to others (Deci & Ryan, 1985). Figure 1 depicts the linkage between the concepts derived from SDT. While the gray boxes represent the concepts developed at the theoretical level, the white boxes represent concepts at the operational level, which are used as research constructs in this study.

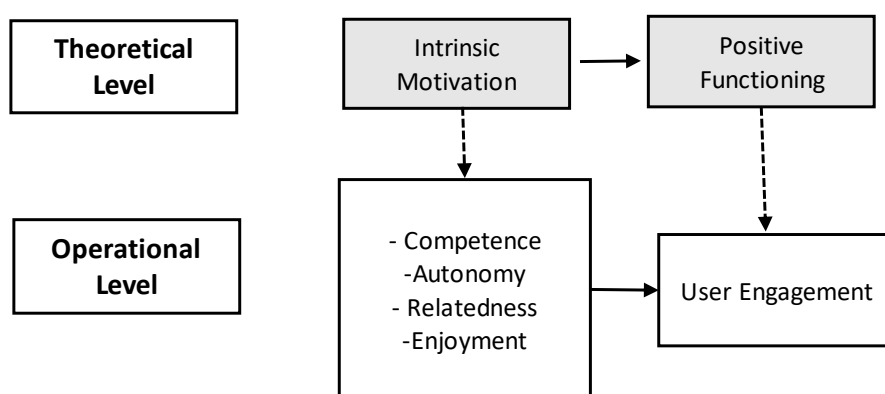


Figure 1: Self-Determination Theory (SDT) adapted from Suh et al., 2015

The second theory used for the development of the theoretical model for the study is MDAT (Hunicke, LeBlanc, & Zubek, 2004). MDAT describes how game design elements influence responses by players. MDAT consists of three components: game mechanics, game dynamics, and game aesthetics. Game mechanics refer to the tools and techniques that are the building blocks of a game, for example points, badges, avatars and leader boards. Game dynamics refer to the run-time behaviour of a game and its interaction with players, for example rewards, competition and self-expression. Game aesthetics refer to players' emotional responses when they interact with a game. Depending on the game dynamics, various emotional responses from individual users can be

expected, such as excitement, rising tension, relaxation or frustration (Suh et al., 2015). MDAT has been developed to theorise about actual games, but is adopted in this study in the context of gamified systems, as gamified systems employ game elements in a non- game context. MDAT explains that game mechanics like points, levels, badges, avatars and leader boards, cause gameplay dynamics (Hunicke et al., 2004) like rewards and competition. Game aesthetics come from game dynamics that stimulate users to compete with others, change levels, leave their mark, purchase game items and create unique characters. Given the purpose of gamification is to make non-game activities fun and enjoyable, we infer that the aesthetics (emotional responses from users) of a gamified system would lead to intrinsic motivation of users. Figure 2 represents the linkage between game mechanics, dynamics, and aesthetics at theoretical and operational levels.

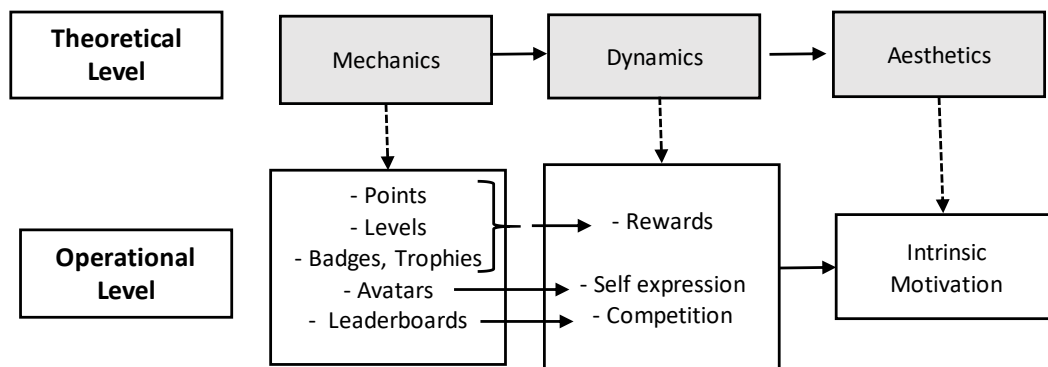


Figure 2: Mechanics-Dynamics-Aesthetics Theory (MDAT) adapted from Suh et al., 2015

Based on SDT, intrinsic motivation is conceptualised in this study as competence, autonomy, relatedness and enjoyment. The link between SDT and MDAT in the theoretical model of the study is therefore intrinsic motivation as shown in Figure 3.

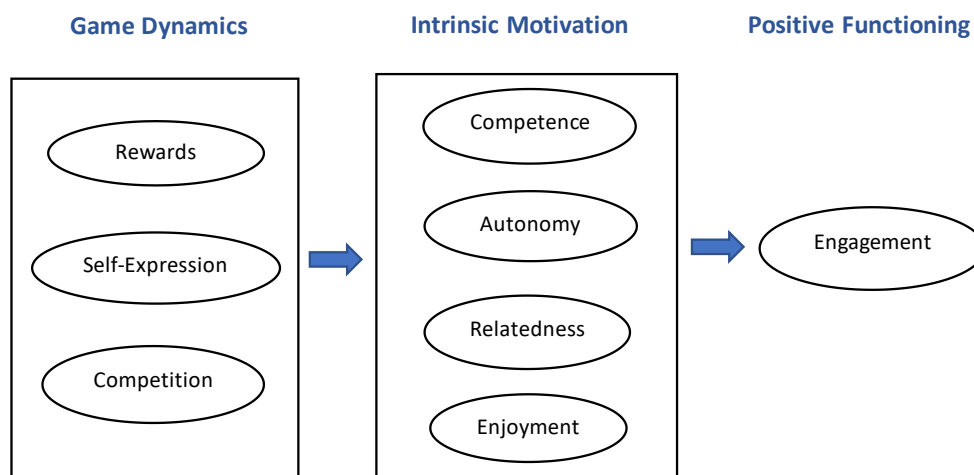


Figure 3: Theoretical model based on an integration of SDT and MDAT

The rewards construct in the theoretical model refers to the perception of users which entails that it is possible for them to earn and accumulate points, and that they will have the possibility to earn more points if they try harder (Suh, Cheung, Ahuja, & Wagner, 2017). Moreover, the self-expression construct refers to the perception of users that it is possible for them to express their identity through game elements in a way that is distinct from others (Suh et al., 2017). Furthermore, the competition construct refers to the perception of users that it is possible for them to compete with

others and compare their performance whilst threatening the status of other users through their active participation (Suh et al., 2017).

Based on the integrated theoretical model as discussed in the preceding section, the following hypotheses are proposed for the current study:

H1a: Competence will lead to engagement in a gamified learning system.

H1b: Autonomy will lead to engagement in a gamified learning system.

H1c: Relatedness will lead to engagement in a gamified learning system.

H1d: Enjoyment will lead to engagement in a gamified learning system.

H2a: Rewards will lead to the experience of autonomy in a gamified learning system.

H2b: Self-Expression will lead to the experience of autonomy in a gamified learning system.

H2c: Competition will lead to the experience of autonomy in a gamified learning system.

H3a: Rewards will lead to the experience of competence in a gamified learning system.

H3b: Self-Expression will lead to the experience of competence in a gamified learning system.

H3c: Competition will lead to the experience of competence in a gamified learning system.

H4a: Rewards will lead to the experience of relatedness in a gamified learning system.

H4b: Self-Expression will lead to the experience of relatedness in a gamified learning system.

H4c: Competition will lead to the experience of relatedness in a gamified learning system.

H5a: Rewards will lead to the experience of enjoyment in a gamified learning system.

H5b: Self-expression will lead to the experience of enjoyment in a gamified learning system.

H5c: Competition will lead to the experience of enjoyment in a gamified learning system.

METHODOLOGY

The research instrument that was used to test the theoretical model of the study was a survey. Multiple-item summated rating scales were used to measure each construct that consisted of a 7-point Likert scale with two anchor points namely (1) "Strongly Disagree" and (7) "Strongly Agree". The items in these scales were adapted from the existing literature. The engagement scale contained 9 items and 3 sub scales namely immersion (3 items), meaning (3 items) and active discovery (3 items) and were adapted from Suh et al. (2017). Scales for competence (3 items), autonomy (3 items) and relatedness (3 items) were adapted from (Sheldon, Elliot, Kim, & Kasser, 2001). Scales for enjoyment (3 items), rewards (3 items), self-expression (3 items) and competition (3 items) were adapted from Suh et al. (2017).

The population for the study was 192 second year Information Technology students at the Central University of Technology in the Free State province, enrolled for the subject Databases II. The theory component of the subject focus on database design, and the practical component of the subject focus on SQL database programming. In the practical periods of these subjects, students were exposed to the "Introduction to SQL" subject on the gamified online learning platform namely Khan Academy (Khan Academy, 2018). Students were exposed to the Khan Academy gamified online platform for the first semester of 2018. After this period, a survey was administered online by making use of QuestionPro. The link to the questionnaire was placed in the learner management system used by students, and students were asked to voluntarily complete the questionnaire. Ethical procedures as stipulated by the Central University of Technology were adhered to.

The relationships between constructs in the theoretical model were analysed for statistical significance through path analysis using structural equation modelling (SEM). Partial least squares (PLS) SEM were selected because it is appropriate for the early stages of theory development (Hair Jr, Sarstedt, Hopkins, & Kuppelwieser, 2014). SMARTPLS 3 were the tool used for the analyses.

RESULTS

Data analysis followed the two-stage analytical procedure. The first stage assessed the measurement model for validity and reliability. The second stage examined the structural model to test the research hypotheses.

Measurement Model

Table 1 contains factor loadings, VIF, T-statistic, composite reliability (CR) and average variance extracted (AVE). In order to assess internal consistency of the measurement model, CR were investigated. All CR values that were between 0.70 and 0.90 can be regarded as satisfactory (Hair Jr et al., 2014). In order to assess convergent validity, AVE were investigated. All AVE values were above the threshold value of 0.5, and therefore convergent validity can be regarded as satisfactory (Hair Jr et al., 2014). Assessment of collinearity were assessed by investigating VIF, and all values were below 5.0, so the collinearity of all constructs were within acceptable levels (Hair Jr et al., 2014).

Table 1: Measurement validity and reliability

	Items	Outer Loadings	VIF	T-statistic	CR	AVE
Engagement	ACD1	0.72	1.69	18.21	0.83	0.51
	ACD2	0.74	1.79	17.46		
	ACD3	0.72	1.69	13.52		
	IMM1	0.62	1.50	10.11		
	IMM2	0.62	1.53	8.47		
	IMM3	0.73	1.76	15.91		
	MEA1	0.79	2.20	21.85		
	MEA2	0.79	2.30	21.52		
Autonomy	AUT1	0.84	1.45	32.84	0.82	0.61
	AUT2	0.81	1.32	23.00		
	AUT3	0.69	1.29	10.13		
Competence	COM1	0.77	1.39	14.60	0.86	0.67
	COM2	0.85	1.62	32.41		
	COM3	0.83	1.54	25.55		
Relatedness	REL1	0.77	1.43	13.11	0.83	0.63
	REL2	0.82	1.52	26.87		
	REL3	0.78	1.26	19.09		
Enjoyment	ENJ1	0.85	1.57	27.48	0.85	0.66
	ENJ2	0.86	1.74	31.14		
	ENJ3	0.72	1.35	11.95		
Competition	COM1	0.83	1.50	24.94	0.81	0.59
	COM2	0.79	1.44	16.82		
	COM3	0.69	1.15	12.48		
Rewards	REW1	0.83	1.64	19.61	0.85	0.65
	REW2	0.81	1.36	25.44		
	REW3	0.78	1.49	13.63		
Self-Expression	SEE1	0.70	1.29	11.84	0.82	0.61
	SEE2	0.81	1.31	21.90		
	SEE3	0.83	1.44	29.60		

Structural Model

Results for the path coefficients in the structural model are shown in Figure 4. From Figure 4 it can be seen that H1a-H1d was supported with enjoyment ($\beta=0.37$), competence ($\beta=0.30$), autonomy ($\beta=0.23$) and relatedness ($\beta=0.14$) all having a statistical significant positive relationship with engagement. Together these four constructs predicted 81% ($R^2 = 0.81$) of the variability of the engagement construct. The following guidelines, presented by Evans (1996) were used to interpret R^2 : very weak (0-4%); moderate (16 – 36%); strong (36-64%) and very strong (64-100%). From these guidelines, it is evident that the predictive power of autonomy, competence, relatedness and enjoyment towards the engagement construct were very strong.

Furthermore, H2a – H2c were supported by the self-expression ($\beta=0.46$), rewards ($\beta=0.26$) and competition ($\beta=0.20$) constructs all having a statistical significant positive relationship with autonomy in the gamified system. In combination, these three constructs predicted 46.9% (R^2

=0.469) the variability of the autonomy construct, displaying strong predictive power according to Evans (1996).

In addition, only H3a and H3b were supported with rewards ($\beta=0.46$) and self-expression ($\beta=0.26$) having a statistical significant positive relationship with competence. Together these two constructs predicted 46.9 % ($R^2=0.469$) of the variability of the competence construct. H3c were not supported with competition not having a statistical significant relationship with competence.

Moreover, only H4b and H4c were supported with self-expression ($\beta=0.39$) and competition ($\beta=0.37$) having a statistical significant positive relationship with relatedness. These two constructs predicted 58.5% ($R^2 = 0.585$) of the variability in the relatedness construct, exhibiting strong predictive power (Evans, 1996). H4a was not supported with rewards not having a statistical significant relationship with relatedness.

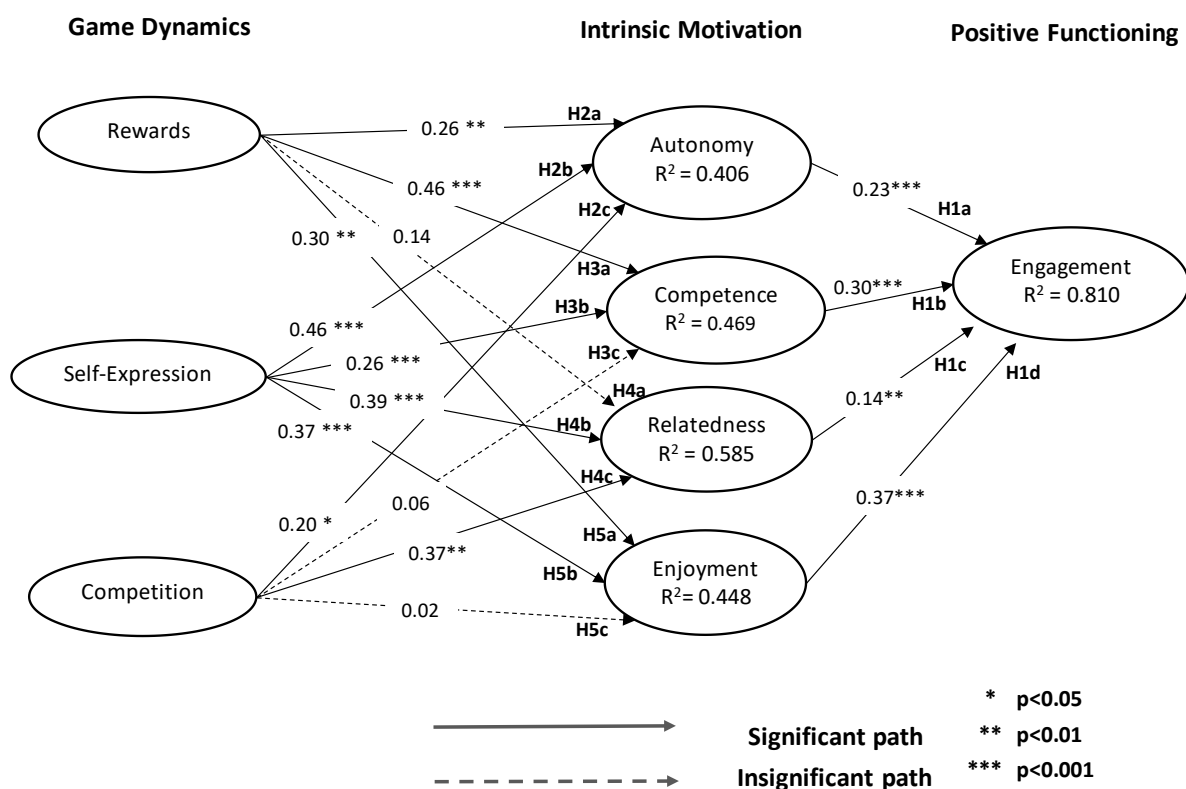


Figure 4: Proposed research model

Lastly, only H5a and H5b were supported with rewards ($\beta=0.30$) and self-expression ($\beta=0.37$) demonstrating a statistical significant positive relationship with enjoyment. In combination, these two constructs predicted 44.8% ($R^2=0.448$) of the variability of the enjoyment construct, which can be categorized, as strong predictive power (Evans, 1996). H5c was not supported with competition not having a statistical significant relationship with enjoyment.

DISCUSSION

The research question driving this study was: How do game design elements work to engage students in a gamified learning system? The results of the study suggest that when the need of students for autonomy, competence, relatedness and enjoyment is met, it will lead to higher levels of engagement with the gamified learning system. Specifically, results suggest that competence,

autonomy, relatedness and enjoyment account for about 81% of the variance of engagement. This implies that ignoring one aspect of the four basic needs may significantly reduce students' engagement levels in gamified learning systems. Moreover, results suggest that various game dynamics influence the basic physiological needs of students for autonomy, competence, relatedness and enjoyment in a gamified learning system. The self-expression game dynamic was the most important element due to the fact that it had a positive relationship with all four physiological needs. The rewards game dynamic was the second most important game dynamic and had a positive influence on autonomy, competence and enjoyment. In turn the competition game dynamic positively influenced autonomy and relatedness. The findings of this study imply that none of the game dynamics suggested in this study should be ignored when attempting to make users more engaged in a gamified system. This is because each dimension of game dynamics play a different role in satisfying different facets of basic needs.

CONCLUSIONS

This study shed light on how various elements in a gamified educational system could lead to higher levels of intrinsic motivation, which in turn can lead to higher levels of student engagement. This study made a theoretical contribution to the growing body of knowledge in gamification research and combined two dominant theories in a novel way to explain the engagement of students in gamified learning environments. The study also made a practical contribution in the sense that it illustrated that a wide variety of game dynamics should be combined in a gamified system in order to engage students. The results of this study could also be used by educators who want to incorporate gamification systems in their training toolkit.

A limitation of the current study is that the population of the study was limited to one province in South Africa. Suggestions for future research would therefore be an invitation to researchers in institutions from other provinces to test the model developed for the study in similar gamified learning environments in order to validate the findings of the current study.

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INFLUENCE OF POINTS IN A GAMIFIED SYSTEM ON PERFORMANCE OF STUDENTS

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ABSTRACT—There has been widespread interest in the usage of gamification in education to improve engagement, motivation and academic performance of students. Limited research that can shed light on the influence of various gamification elements on the academic performance of students is currently available. The objective of the study was to investigate the influence that points earned by students in a gamified learning system, had on time spent in the gamified system and on academic performance of students. The population of the study consisted of 192 second year Information Technology students enrolled at the Central University of Technology in South Africa. Metrics regarding points earned by students, and the amount of time spent in the gamified learning environment were extracted from the Khan Academy gamified learning system. The results indicated that the points students received motivated them to spend more time in the learning environment, which in turn lead to higher academic performance. The results of this study could assist instructors in higher education institutions to incorporate gamified learning environments into their learning offerings.

Keywords: Gamification, Khan Academy, Points, Academic Performance

INTRODUCTION

The most important objective of teaching is to promote learning. To accomplish this goal, teachers implement various teaching tactics such as problem-based learning and cooperative learning, which have been proved to have a positive effect on learning (Ortiz, Chiluiza, & Valcke, 2017). Gamification, the use of game elements in non-game contexts, is a reasonably novel approach that has shown a potential benefit to learning (Kapp, 2012). Since gamification became popular, less than a decade ago, (Deterding, Dixon, Khaled, & Nacke, 2011) it has been used for educational purposes, as well as in other settings such as marketing and health (Seaborn & Fels, 2015). When scrutinising reviews on how researchers have studied gamification in education, most studies report an emphasis on engagement and motivation as main variables (Fui-Hoon Nah, Zeng, Rajasekhar Telaprolu, Padmanabhuni Ayyappa, & Eschenbrenner, 2014, Ortiz, Chiluiza, & Valcke, 2016). There is currently a lack of studies that investigate the impact of gamification on learning outcomes. This lack of research findings is a definite obstacle for gamification to be accepted as a fruitful teaching approach (Ortiz et al., 2016). Moreover, most studies that do report the impact of gamification on learning outcomes, do not have any theoretical underpinning on which their research is based. Without a theoretical model associating the specific approaches taken by the designers of instructional content to gamify learning with the outcomes of those approaches, it will not be transparent why these techniques influence outcomes as they do. This gap limits the generalisability of gamification research and provides ambiguous recommendations to practitioners in the gamification domain. This study will therefore use the Theory of Gamified Learning in order to empirically test the effect that points obtained in a gamified learning system have on time spent in the gamified environment and academic performance. The paper is structured to present previous research that was conducted on the effect of gamification on academic performance followed by the research model and hypotheses. Subsequently, the methods, results, discussions and conclusions are discussed.

PRIOR RESEARCH ON THE INFLUENCE OF GAMIFICATION ON LEARNING PERFORMANCE

Previous empirical studies that reported the influence of gamification on academic performance were reviewed for the past 3 years (2015-2017). These studies are summarised in Table 1. The following information was reported for every study: 1) authors, year of study, country of study, 2) sample size of study, 3) game elements used, 4) the course or subject that was gamified as well as the educational level, with 'PS' indicating primary school, 'SS' indicating secondary school and 'HE' indicating higher education settings, 5) the duration of the study and 6) the effect that the implementation of gamification elements had on the academic performance of students. The studies were sorted according to year of study, and then by the surname of the first author. From the 21 studies that were reviewed, ten reported that gamification had a positive effect on the academic performance of students. In contrast, ten studies reported that gamification had no statistical significant effect on the academic performance of students, while one study reported a negative effect.

Table 1: Previous studies on the effect of gamification on academic performance

Authors, year of study, (country)	N	Game Element	Course Subject and (Educational Level)	Duration	Effect on academic performance
Buhagiar & Leo, 2017 (USA)	60	Interactive media widgets	Applied Business Technology.(HE)	1 semester	None
Elshemy, 2017 (Oman)	68	Pictures, voice, interactive elements, feedback, virtual currency rewards	Science (SS)	Not mentioned	Positive
Nakada, 2017 (Japan)	1658	Challenges, points	Math (HE)	7 years	None
Özer & Bicen, 2017 (Turkey)	60	Leaderboard	Teacher Education Qualification (HE)	1 year	Positive
Papp, 2017(Canada)	22	Points, leaderboard	Math (PS)	2 years	Positive
Buckley & Doyle, 2016 (Ireland)	100	Ranking, virtual currency	Tax System (HE)	3 weeks	Positive
De-Marcos, Garcia-Lopez & Garcia-Cabot, 2016 (Spain)	379	Trophies, badges, challenges, leaderboard	Qualification for ICT Users (HE)	10 weeks	None
Draz, Abdennadher & Abdelrahman, 2016 (not mentioned)	1078	Challenges, quests, achievements	Programming (HE)	4 months	Positive
Hew, Huang, Chu & Chiu, 2016	64	Points, badges, leaderboard	Designing Questionnaire	18 days	None
Sanmugam et al., 2016 (Malaysia)	29	Points, badges, leaderboard	Science Form 1 (SS)	8 weeks	Positive
Attali & Arieli-Attali, 2015 (USA)	693	Points	Math (PS)	5 days	None

Auvinen, Hakulinen & Malmi, 2015 (Finland)	469	Badges	Data Structures and Algorithms (HE)	1 semester	Positive
Hakulinen, Auvinen & Korhonen, 2015 (Finland)	281	Badges	Data Structures and Algorithms (HE)	1 semester	None
Hanus & Fox, 2015 (USA)	71	Badges, leaderboard	Communication (HE)	16 weeks	Negative
Jang, Park & Mun, 2015 (South Korea)	114	Avatars, points, levels, hearts	Using Adobe Photoshop (HE)	Not mentioned	Positive
Kaur & Geetha, 2015 (India)	100	Levels	Computer Programming (HE)	Not mentioned	Positive
Laskowski, 2015 (Poland)	76	Points, badges leaderboard	Software Engineering (HE)	2 years	None
Paiva, Barbosa, Batista, Pimentel & Bittencourt, 2015 (Brazil)	100	XP, badges	Math (SS)	Not mentioned	None
Papadopoulos, Lagkas & Demetriadis, 2015 (not mentioned)	56	Ranking	Network Planning and Design (HE)	14 days	None
Pedro, Lopes, Prates, Vassileva & Isotani, 2015 (Canada)	16	Points, badges, feedback, and ranking	Math (PS)	Not mentioned	None
Sousa-Vieira, López-Ardao, Fernández-Veiga, Rodríguez-Pérez & López-García, 2015	not stated	Ranking, badges	Computer Networks (HE)	14 weeks	Positive

Table 1 shows that the most popular gamification element used, was badges, with ten studies incorporating it in their gamification environment, followed by points used in eight studies, leader boards used in seven studies, ranking used in four studies, and challenges, virtual currency, levels and feedback used in two studies each. Other gamification elements like avatars, quests and achievements were only used in one study. Furthermore, the largest number of studies (seven) focused on information technology related subjects, including programming, software engineering and networking. The second largest number of studies (five) focused on math in primary school, secondary school and higher education settings. In addition, the countries that were most prominent in the studies were USA (three), Spain (two), Canada (two) and Finland (two), with no studies that were conducted on the African continent. Sample size of the studies varied from 16 to 1658 and the duration of the studies varied from five days to two years.

DEVELOPMENT OF RESEARCH MODEL AND HYPOTHESES

Landers (2014) introduced the Theory of Gamified Learning (TGL) to explain the causal paths by which gamification interventions can influence outcomes for students across a wide variety of contexts (see Figure 1).

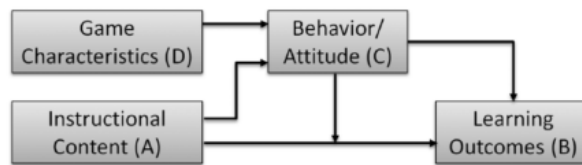


Figure 1: Theory of gamified learning (Landers, 2014)

According to the TGL, gamification characteristics influence behaviour and/or attitude and this in turn will influence learning outcomes (see Figure 1; $D \rightarrow C \rightarrow B$). In this study the causal path, $D \rightarrow C \rightarrow B$ will be tested as shown in Figure 2.

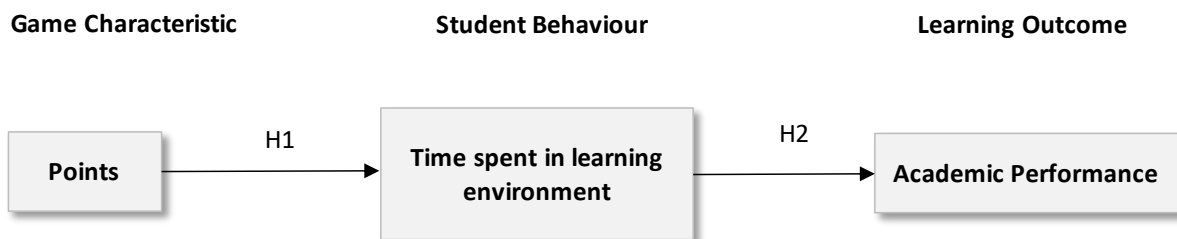


Figure 2: Research Model

The game characteristics in the research model of the study is the points that students earned in the gamified learning environment, and the student behaviour in the research model is the amount of time that students spent in the gamified learning environment. The learning outcome were the academic performance of students for the topics that were covered in the gamified environment.

Based on the conceptualisation of the TGL, it was predicted that the amount of points that students earn in the gamified learning environment will motivate students to spend more time in the gamified environment (Lewis, Swartz, & Lyons, 2016), therefore it was predicted that there will be a positive relationship between points and time spent. Consequently, the first hypothesis of the study is:

H1: Points that students earn in a gamified learning environment will be positively related to time spent in the learning environment.

When turning to the second part of the research model namely the relationship between time spent in the learning environment and academic performance, a review of prior research in both education and workplace learning reveals that increased time-on-task increases learning across various learning settings (Brown, 2001). From a century of research, it is now acknowledged that students who practice and engage with a task more often produce greater knowledge and skill than those who spent less time engaging in a task (Ericsson, Krampe, & Tesch-Romer, 1993). Therefore, it was predicted that time spent in the gamified learning environment will be positively related to academic performance. As a result, the second hypothesis of the study is:

H2: Time spent in the gamified learning environment will be positively related to academic performance.

RESEARCH METHODOLOGY

The population for the study was 192 second year Information Technology students at the Central University of Technology in the Free State province, enrolled for the subject Databases II. The theory component of the subject focuses on database design, and the practical component of the subject

focuses on SQL database programming. In the practical periods of these subjects, students were exposed to “Introduction to SQL”, a subject on the gamified online learning system namely Khan Academy (Khan Academy, 2018). Students were exposed to this system for the first semester of 2018. In the Khan Academy learning system, students received points after watching videos and successfully completing assignments. Students had access to a report showing precisely when and how many points they received for each completed activity. In order to collect data for the study, the instructor created a subject on Khan Academy. All students were thereafter invited to join this subject and were provided with a unique access code to gain access to the subject. The instructor loaded weekly “assignments” for students in this subject and these assignments comprised of the content that form part of the “Introduction to SQL” subject on Khan Academy. The instructor of a subject on Khan Academy can download the amount of points students have accumulated until a given date and can also download the total amount of time a student spent inside the subject on Khan Academy. This information was used to test H1. Throughout the semester students wrote various SQL tests that were based on the content that was covered on Khan Academy and their final mark for these tests was used to test H2. The relationship between constructs in the research model was analysed for statistical significance through path analysis using structural equation modelling (SEM). Partial least squares (PLS) SEM was selected because it was appropriate for the early stages of theory development (Hair Jr, Sarstedt, Hopkins, & Kuppelwieser, 2014). SMARTPLS 3 was the tool used for the analyses.

RESULTS AND DISCUSSIONS

The results of the path analysis are shown in Figure 3.

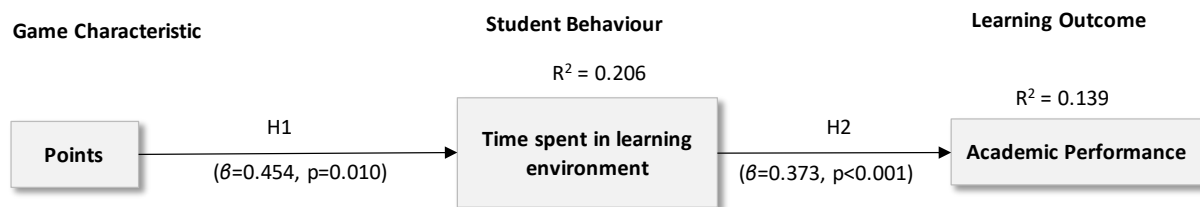


Figure 3: Path analysis of research model

As can be seen from Figure 2, there is a statistical significant positive relationship between points and time spent in the learning environment ($\beta=0.454$, $p=0.010$). In addition, points could also predict approximately 21% ($R^2 = 0.206$) of the variability in the amount of time students spent in the learning environment. The following recommendations of Cohen (1988) were used to interpret the effect size of R^2 namely: $R^2 = 0.01$ -> small effect, $R^2 = 0.09$ -> medium effect and $R^2 = 0.25$ -> large effect. According to these guidelines, the strength of the positive effect that points have on time spent just fell short of a large effect. Moreover, there is a statistical significant positive relationship between time spent and academic performance ($\beta=0.373$, $p<0.001$). Furthermore, time spent could also predict approximately 14% of the variability in academic performance, a medium strength effect according to Cohen (1988). Therefore, both H1 namely: “Points that students earn in a gamified learning environment will be positively related to time spent in the learning environment” and H2 namely: “Time spent in the gamified learning environment will be positively related to academic performance” of the study was accepted. From the preceding discussion, it can be seen that the points students earned in the gamified learning environment motivated students to spend more time in the environment which lead to higher academic performance. The positive effect that points, therefore, have on academic performance is due to the increased amount of time that students

spend in the learning environment. This finding is in line with prior research that showed a positive relationship between the use of points in a gamified environment and academic performance (Papp, 2017; Sanmugam et al., 2016).

CONCLUSIONS

The aim of this study was to investigate the effect that points obtained in a gamified learning system had on time spent in the gamified environment and the effect that time spent in the gamified system has on academic performance. This study has shown that points earned in a gamified programming learning system could lead to students spending more time in this system and this could lead to higher academic performance. The implication of the findings of this study is that gamification elements in a gamified system could motivate students to spend more time using these systems which could lead to improved performance of students. Moreover, the Khan Academy gamified learning environment could be a very conducive environment to test the amount of points students earn and the time they spend in the environment on academic performance due to the fact that these metrics are provided by the system, eliminating self-report errors.

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