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Message from the Conference Chair

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’.

This year marks the 10th anniversary of the ISTE Conference. The Conference is a brainchild of the founding head of ISTE, Prof HI Atagana. There was scepticism within ISTE when he presented the thought of establishing a conference. He nevertheless took it upon himself to prepare requisite documentation for the University to sanction the Conference and even provide seed funding. Furthermore, it is heart-warming to note that, since its inception, the Conference has yearly produced accredited proceedings, had revered researchers as plenary speakers, drawn participants from various corners of the globe, devoted time slots on capacity development, helped students reshape and fine tune their studies after presenting their research work either in parallel sessions or mock viva, provided opportunities for people to interact, share ideas and make connections and, lastly, enabled people to have first-hand experience of and admire the bush. Undoubtedly, through the Conference, ISTE has managed to live up to its mission of providing further insight into issues pertaining to the teaching and learning of mathematics, science and technology and providing enriching exposure to students in MSTE.

Lastly, ISTE Conference sincerely thanks the Unisa College of Graduate Studies; South African National Parks (SANPARKS) 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
ISTE Conference Chair
Review Process

The ISTE Editorial Committee received 65 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 65 manuscripts received, 23 were rejected. Of all the manuscripts received, 42 (65 %) were eventually published in the ISTE 2019 Conference Proceedings. Of this number, 89 % manuscripts were authored by non-Unisa affiliates.
Acknowledgements

The organising committee of ISTE 2019 is indebted to the following organisations/institutions whose generous donations contributed to the success of the conference:

University of South Africa – College of Graduate Studies

South Africa National Park

Vivali Publishers and Bookseller
Infusing Relevance into Student Science Learning Through Contextualized Pedagogy: Learning as Unpacking Knowledge Imbedded in Local Scientific Phenomena

ABSTRACT: I draw on Hull’s (1993) contextual leaning theory to place this discussion in the framework that envisions learning as occurring only when learners process new information in ways that make it meaningful in their frame of reference. This approach assumes that the mind naturally seeks meaning in a context by searching for relationships that make sense and resonate with the students’ cultural backgrounds. Accordingly, contextual learning should be organized in ways that allow students opportunities to engage in real world problem solving activities (Karweit, 1993). Africa’s desire to industrialize by 2030 requires recognition that students’ worldviews of industrialization (embodied in science and technology) evolve from relevant local contexts and can be an enabling motive for transforming the locally evolving industries.

RESUME: Professor Samson Madera Nashon is Head of Department of Curriculum and Pedagogy, Faculty of Education at the University of British Columbia (UBC). He holds Doctor of Education (Ed.D) degree from the University of Toronto (2001).

His research focuses broadly on ways of teaching and learning the sciences, and is characterized by three main emphases: Understanding the nature of science curriculum and instruction and development of theoretical and pedagogical models to improve the practice of science teaching.
Bringing design to technology & education: Going from Artifacts and processes to Systems and Culture

ABSTRACT: It often appears as if decades of research, development and investment in educational technology have limited effect in actual classrooms. I argue this is because we have not paid enough attention to how educational technology works at the level of systems and culture. I present a new framework, the Five Discourses of Design, that can help us learn from the past and possibly carve a new path for the future. I conclude with examples of how the framework is being applied in the work we are doing at the Teachers College and with suggestions for future research and practice.

RESUME: Dr. Punya Mishra is Associate Dean of Scholarship & Innovation and Professor in the Division of Educational Leadership & Innovation in the Mary Lou Fulton Teachers College at Arizona State University. He also has an affiliate appointment in the Herberger Institute for Design and the Arts.

He is internationally recognized for his work in technology integration in teaching; the role of creativity and aesthetics in learning; and the application of design-based approaches to educational innovation. Professor Mishra (in collaboration with Dr MJ Koehler) proffered the Technological Pedagogical Content Knowledge (TPACK) framework, which has been described as being “the most significant advancement in the area of technology integration in the past 25 years.”
Digital interoperability: the new frontier for academic integrity in education

ABSTRACT: While several role players in the post-school education and training (PSET) system are moving towards the development of information communication technology (ICT)-enabled solutions and platforms in South Africa to improve operational efficiency and governance, these developments are largely uncoordinated. The interface between these different developments lack interoperability and stands to benefit from improved coordination, which will enhance efficiencies within the PSET system. This is in line with the decision for shared services to be developed across the Sector Education and Training Authorities (SETAs) in particular, but also in relation to the interface between SETAs, the Department of Higher Education and Training (DHET) and other systems, including universities. We now have the technology to develop self-sustaining electronic platforms for collaboration and learning opportunities, including the utilisation of data. These new digital ecosystems can provide us with limitless opportunities to rethink academic integrity, standards and qualifications in a new world based on the principles of interoperability. As authors based at a non-profit research organisation and a SETA, we have been extremely privileged to be at the nexus of many of these developments. In this paper we share the emerging experiences and insights that are part of a collaborative project in the PSET system in South Africa. In particular, we explore two concepts central to the undertaking, namely interoperability and a digital ecosystem. The paper ends with a reflection on the nascent implications of these concepts on academic integrity in PSET, looking at this from a technological perspective.

RESUME: James Keevy is a policy researcher that works in the education and training sector. He has conducted and overseen various initiatives related to national, regional and international qualifications frameworks in Africa, and also, further afield. His research into qualifications, the recognition of learning, and the professionalisation and migration of teachers have been widely published and presented. James is the Chief Executive Officer at JET Education Services which is an independent public benefit organisation located in Johannesburg, South Africa, that was founded in 1992. His responsibilities at JET include working with government, the private sector, international development agencies and education institutions to improve the quality of education, and the relationship between education, skills development and the world of work.
Science Education and Transformative Learning: Working towards future sustainability in more socially just ways that include indigenous heritage practices and the Sustainable Development Goals (SDGs)

ABSTRACT: 21st Century Science has become centred on global matters of concern like climate change, biodiversity loss and planetary system degradation that call for education towards the transformative survival of humanity in a changing world. Towards resolving these matters of concern, all of the current world governments have signed off on the Sustainable Development Goals (SDGs) and Education 2030 has integrated these as as a transformative agenda for future sustainability. Alongside this, Southern Africa and many countries of The South are emerging from an extended period of colonial modernisation amidst calls to decolonise the curriculum and include indigenous heritage in teaching and learning. Teachers are thus faced with a dual challenge of inclusion, namely

- including indigenous knowledge (Heritage) and
- working with the SDGs as a global agenda for future sustainability in an already full curriculum within which students are often alienated and underperforming.

The presentation points to how we might best work with the SDGs and expand existing Teach - Task - Test progressions to include plural knowledge systems in transformative processes of teaching and learning within existing subject disciplines. It explores tools for

- working with the SDGs,
- mediating learning around intergenerational heritage practices and
- expanding existing teaching, learning and assessment practices

These are explored as a research agenda for clarifying school subject-based ‘T’ Learning in a changing world.

RESUME: Rob O’Donoghue is Professor Emeritus at the Environmental Learning Research Centre (ELRC), Rhodes University. In his research in environment and sustainability education, he has given close attention to indigenous knowledge practices and inclusive, action learning in post-colonial curriculum and community contexts. Recent work with critical realism has been centred on transformative social learning and expanding the scope of evaluation in Education for Sustainable Development. His research has informed the Fundisa-for-Change teacher professional development programme and the Amanzi-for-Food initiative on local food production using rainwater harvesting to mitigate climate variability in the Eastern Cape. His most recent work on ethics-led transformative learning has been an ESD Expert-Net initiative on Handprint-CARE. This was undertaken within the ELRC T-Learning work with the ISSC and in collaboration with colleagues in Mexico, Germany, India,
Norway, Malaysia and Japan. The open-ended research and materials development work is centred on ‘learning to look after others so as to best care for ourselves and the surroundings we all share,’ the challenge of future equity, peace and sustainability in a changing world.
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ABSTRACT: The manner in which science is communicated is important to the way in which concepts are understood by the recipient. Multiple representations involving verbal, graphical, symbolic or experimental modes can help students to better understand science phenomena. In this study the representational competence and fluency of pre-service science teachers (N=82), who were paired to present a model that illustrates series or parallel circuits, were analysed. In addition, the extent to which simulations constrain or afford understanding in the domain was also examined. The results indicate that 56% of pre-service science teachers use simulations to afford a better understanding of electric circuits while 59% can construct an appropriate model to demonstrate concepts in direct-current electricity. However, only 7% incorporate symbolic representations to show an enhanced understanding. There is also a need for students to improve their verbal skills to better explain concepts. Some implications of this study are outlined.

Keywords: multiple representations; competence; simulations; inquiry-based science teaching

INTRODUCTION

Science teaching involves an array of strategies or methods to convey the meaning of concepts or phenomena, whilst science learning entails the development of a common, shared understanding of scientific concepts. Daniel, Bucklin, Leone and Idema (2018, p.3) posited that “in science, representations are used to display data, organize complex information, and promote a shared understanding of scientific phenomena”. These representations involve verbal communication, graphical and tabular displays, diagrams, models, equations, or simulations of the concepts.

In this paper we explore the representational competence and fluency of pre-service science teachers as they develop their pedagogy in science education. In particular, we examine how students enrolled in a Natural Sciences module in a Bachelor of Education programme use multiple representations (MRs) to represent concepts relating to direct-current electricity. These students will ultimately teach Natural Sciences in the Senior Phase (Grade 7 – 9) and would need to develop their skills as they engage with the curriculum in an inquiry-based science teaching classroom. All of this is neatly encapsulated in the notion of Pedagogical Content Knowledge (PCK) as espoused by Shulman (1986, p.9):

“... I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those 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 others”.

Multiple representations are therefore key to the development of the science teacher's pedagogical repertoire to promote understanding of subject disciplinary knowledge.

THEORETICAL BACKGROUND

Inquiry-based Science Teaching (IBST)

In this study, Inquiry-based Science Teaching is characteristic of teachers who “structure science activities so that students are required to explain and justify their understanding, argue from data and defend their conclusions” (National Research Council, 1996, p.50). Constantinou, Tsivitanidou and Rybska (2018) advocated that pre-service and in-service science teachers be given opportunities to familiarise themselves with various inquiry-based approaches. This pedagogical approach must be infused in the classroom and the research evidence produced can inform reform efforts in science education (Buck, Latta & Leslie-Pelecky, 2007). The latter found that there is a need to enhance our efforts to ensure science teachers have the content knowledge necessary to facilitate inquiry-based learning. These
classroom strategies allow pre-service science teachers to explore the complexity of teaching science through inquiry in a controlled, nontargeting environment (Qablan & DeBaz, 2015).

Ireland et al. (2014) proposed that there is evidence to suggest that Inquiry Teaching can lead to strong learning outcomes for students which include developing accurate scientific knowledge and skills, understanding and content knowledge of science. When learners are exposed to an IBST and learning environment they are also able to link phenomena to their everyday experiences (Constantinou et al., 2018). Primary school teachers have difficulties in being effective inquiry-based science teachers because they tend to lack knowledge concerning how science inquiry works and, particularly, how to implement inquiry-based teaching in their classrooms (Alake-Tuenter et al., 2012). This serves as further motivation to engage pre-service science teachers in IBST and learning activities to empower them as future facilitators of such activities.

MULTIPLE REPRESENTATIONS IN SCIENCE EDUCATION

According to Tang, Degado and Moje (2014, p.306) “representations are artefacts that symbolize an idea or concept in science (e.g., force, energy, chemical bonding) and can take the form of analogies, verbal explanations, written texts, diagrams, graphs, and simulations”. The different forms are used to communicate science in a visual way and depend on the receiver’s ability to make sense of it which is consistent with scientific thinking (Daniel et al., 2018). It is often the case that some phenomena are visible at a macroscopic level, but in order to understand it requires a visual representation to explain what happens at a microscopic level. For example, in redox chemistry we can observe that zinc metal immersed in a solution of copper sulphate has a deposit that forms on it as shown in Figure 1. The explanation for this phenomenon requires visualisation of atoms and ions that are not visible to the naked eye.

![Figure 1: Macroscopic and microscopic representation of zinc metal reacting with a solution of copper sulphate](image)

Multiple representations refer to the practice of re-representing the same concept through different forms, including verbal, graphic, and numerical modes, as well as repeated student exposures to the same concept (Prain & Waldrip, 2006). An important aspect is the ability of the student to interact between the different modes and to translate from one mode to another.
The challenge is to create a teaching and learning environment which is conducive to such interactions. There is a growing body of evidence to support the value of student-generated representations in promoting learning (Waldrip & Prain, 2012). This is also underpinned by a strong pedagogical justification as students learn more effectively when they use appropriate representations. The focus of this study is on the representational competence and fluency of students as they build a model to illustrate direct-current electric circuits, and explain their observations using different modes. We also examine the use of simulations as an affordance or constraining representational mode in this disciplinary context.

Representational competence is a way of describing how a person uses a variety of perceptions of reality to make sense of and communicate understandings, whereas representational fluency is the process of translating and moving within and between representations to understand a concept (Daniel et al., 2018). The former is static and refers to the student’s ability to use representations while the latter is a dynamic process of navigating between representations. The types of representations are illustrated in Figure 2.

![Figure 2: A representation model indicating categories of competence and fluency (adapted from Lesh & Doerr, 2003)](image)

Various studies have attempted to measure students’ representational competence (Kozma & Russell, 2005; Halverson & Friedrichsen, 2013; Mishra et al., 2018). These are all context specific such as in chemical education, biological education, etc. Students need to be able to select the appropriate representation according to a need to achieve a particular purpose (Prain & Tyler, 2013). Daniel et al. (2018, p.4) have argued that “to determine students’ representational competence, representational fluency must also be addressed”.

In this study a framework has been developed to measure students’ representational competence and fluency as shown in Table 1.

The following research questions are addressed in this study:

What is the representational competence and fluency of pre-service science teachers in the domain of direct-current electricity?

To what extent do simulations afford or constrain pre-service science teachers’ understanding of concepts in direct-current electricity?

**RESEARCH METHODOLOGY**

A quantitative research methodology was used which essentially allows for numerical data to be collected (Mertens, 2009). A group of second year pre-service science teachers (N=82) were paired in a Natural Sciences Education module in an IBST classroom at a South...
African university. They had to complete a project on electrical circuits at the end of a unit on current electricity. The model that they built had to illustrate how series or parallel electrical circuits work. They also had to explain what was observed using different representations, but importantly a simulation was required. All of this was video-recorded and later analysed according to the levels in Table 1.

Each representation mode was coded and captured in a spreadsheet. No attempt at any representation was indicated as zero (0). The frequency of each level for a particular representation was tallied and expressed as a percentage as shown in Table 2.

Table 1: Representational competency and fluency levels

<table>
<thead>
<tr>
<th>Representation</th>
<th>Competency &amp; fluency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low-level (1)</td>
</tr>
<tr>
<td></td>
<td>Medium-level (2)</td>
</tr>
<tr>
<td></td>
<td>High-level (3)</td>
</tr>
<tr>
<td>Graphical (Graphs / Diagrams/ Simulations)</td>
<td>Inappropriate graphical illustration that is not linked to the experimental, symbolic or word representation modes. Student demonstrates incorrect scientific understanding of concepts.</td>
</tr>
<tr>
<td>Experimental (Hands-on/model building)</td>
<td>Inappropriate experimental illustration that is not linked to the graphical, symbolic or word representation modes. Student demonstrates incorrect scientific understanding of concepts.</td>
</tr>
<tr>
<td>Symbolic (mathematical equations/formulae)</td>
<td>Inappropriate symbolic illustration that is not linked to the experimental, graphical or word representation modes. Student demonstrates incorrect scientific understanding of concepts.</td>
</tr>
<tr>
<td>Words (verbal/written text)</td>
<td>Inappropriate use of words that is not linked to the experimental, symbolic or graphical representation modes. Student demonstrates incorrect scientific understanding of concepts.</td>
</tr>
</tbody>
</table>
RESULTS

Table 2: Percentage representational competence and fluency at each level for pre-service science teachers

<table>
<thead>
<tr>
<th>No attempt</th>
<th>Graphical (Graphs / Diagrams/ Simulations)</th>
<th>Experimental (Hands-on/model building)</th>
<th>Symbolic (mathematical equations/formulae)</th>
<th>Words (verbal/written text)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12%</td>
<td>5%</td>
<td>90%</td>
<td>5%</td>
</tr>
<tr>
<td>low-level</td>
<td>0%</td>
<td>5%</td>
<td>0%</td>
<td>2%</td>
</tr>
<tr>
<td>medium-level</td>
<td>32%</td>
<td>32%</td>
<td>2%</td>
<td>46%</td>
</tr>
<tr>
<td>high-level</td>
<td>56%</td>
<td>59%</td>
<td>7%</td>
<td>46%</td>
</tr>
</tbody>
</table>

DISCUSSION OF RESULTS

It is evident that 90% of the groups did not indicate any symbolic representation because the main focus was on the use of simulations. The 7% who used equations enhanced their explanation and made clear links between the different modes of representation. Twelve percent of the students did not attempt to use simulations or diagrams to explain their circuit while 32% and 56% were at the medium and high level respectively. This means that they were able to make partial or appropriate links by using simulations. This also shows that simulations do afford rather than constrain students’ understanding of concepts in direct-current electricity.

It is noteworthy that 59% of the models were appropriate, but students’ ability to explain concepts verbally using scientific language is still problematic.

CONCLUSION

It has been shown in this study that by providing students an opportunity to develop their skills through inquiry they are able to formulate explanations using different representations. This also allows them to link the science concepts to their everyday experiences such as
current electricity. The value of student-generated representations depends on how they manage to internalise these artefacts that represent a concept in science. The representational competence and fluency of 56% of pre-service science teachers is at a high-level when it comes to using simulations to explain concepts in direct-current electricity, and 59% are competent at building a model. This indicates that simulations help to promote understanding in the domain.

It is recommended that students get more explicit instructions to incorporate symbolic representations in their explanations as well as opportunities to hone their argumentation skills.

ACKNOWLEDGEMENTS
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REFERENCES


A REVERSE ORDER LIFE CYCLE APPROACH TO ENHANCE SYSTEMS ENGINEERING EDUCATION AT UNDERGRADUATE LEVEL

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ABSTRACT – The advances of Industry 4.0 lead the transition into the era of complex systems, requiring systems solutions for complex problems, increasing the interest in the development of systems engineers. However, traditional systems thinking may lose its effectiveness in this new context, which leads to a challenge in systems engineering education. This research aims to better prepare systems engineers of the future by addressing the disconnect which exist between systems engineering education at undergraduate level, and the real-life complex systems seen in society today though the implementation of a reverse order life cycle approach.

By following the reverse order life cycle approach with a familiar electrical appliance, such as the electric kettle, in the classroom, undergraduate systems engineering students were able to gain the necessary insight and understanding regarding the dynamics of complex systems the underlying systems engineering concepts.

Keywords: Engineering education, Industry 4.0, Reverse Life Cycle, Systems Engineering

INTRODUCTION AND BACKGROUND

The advances stemming from Industry 4.0 created unprecedented complexity of technological development and social interaction. Industry 4.0 can be defined as the utilization of new digitized and connected industrial systems, which are expected to yield extensive industry-spanning opportunities (Kiel, 2017). These connected systems will be challenged by the advances in technology, proliferation of connected sensors, increased computational ability, massive data storage availability and the progress in machine learning or artificial intelligence (Gershwin, 2017). As industry and government become more dependent on systems solutions for complex problems and as procurement agencies increasingly promote systems engineering, there is increasing interest in the development of systems engineers (Davidz, Nightingale & Rhodes, 2005).

Systems Engineering (SE) is defined by the International Council on Systems Engineering (INCOSE) as "an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle" (INCOSE, 2017). In the light of Industry 4.0, industry and academia have expressed concern that systems engineers may not be prepared for the complexity and interconnectivity which new Industry 4.0–driven systems present. The fundamental changes within systems posts one of the biggest challenges for engineering design and also for SE engineering education (Hester & Adams, 2015; Motyl et al, 2017; Von Solms & Marnewick, 2017) to increase (Seymour & Luman, 2011), and be accelerated (Davidz et al, 2005).

The necessity for a SE orientation in electrical engineering education was expressed by Sage as early as 1979 (Sage, 1979). The needs associated with SE education are challenging, as undergraduate engineering students rarely have the insight and understanding in the underlying system dynamics of these complex systems. Students generally have limited engineering exposure to and experience in the complexity of systems and advanced technology as prevalent in society today (Subramanian & Dubey, 2012). These challenges facing undergraduate SE education can be summarized as follows:

- Limited experience in systems thinking of undergraduate engineering students;
- Complexity of even simple technological devices;
- Monetary cost of following the complete SE model to cover the whole product lifecycle;
- Limited time availability for a course in Systems Engineering;
Large undergraduate class size of typically more than 100 students.

Wasson (2004) comments in his book entitled “System Engineering, Analysis, Design, and Development” that the focus of SE courses at many universities globally are lacking, as students are taught the activities of SE, such as writing specifications, developing designs and performing system integration and testing, but no multi-discipline problem-solving and solution development methodologies that can be applied to the system. He further comments that academic instructors “often lack industry SE experience to be cognizant of the problem.” And that they teach a methodology which is “congruent with academic research and scientific inquiry methodologies” which are not consistent with proper SE activities (Wasson, 2004, p.34).

Due to the abovementioned challenges of SE education universities, not all academic institutions have coped with the SE educational challenges, resulting in an under supported industry facing a severe lack of professionals who have mastered the fundamentals of SE (Bougaa et al, 2017). This paper aims to address some of the challenges associated with SE education by proposing reverse order life cycle (ROCL) approach in an undergraduate electrical engineering programme. The layout of the paper is as follows: the next section presents the methodology followed in this research. Thereafter, an overview on the SE course is presented, followed by the assessment of learning as well as a conclusion.

METHODOLOGY

PEDAGOGICAL APPROACH

The pedagogical approach followed in the classroom is based on exposing the students to the concepts of SE through traditional teaching methods combined with engaged learning sessions. A single SE topic was covered every week in one theoretical class and a practical session. Carefully constructed, goal-oriented activities relevant to the course material has been proven to challenge students to engage in learning activities through doing, enabling the students to gain the theoretical knowledge of the subject and learn to apply the gained knowledge in real world applications (White, 2001). Goal-directed practice avoids simply transferring factual knowledge from lecturer to learner, but aims to assist in the better understanding, retention and application of new information, improving the quality of learning (Wood, 2003; Ambrose et al, 2010).

The practical sessions were sequenced to allow a natural progression in developing the students’ understanding of the systems engineering concepts. All activities and exercises were constructed to cover a single SE topic, where the introduction and integration of new tasks and concepts were incorporated in a staggered manner. Such a staggered approach enables students to become proficient in a task before being overwhelmed by new information and actions, which helps students develop mastery in a subject (Ambrose et al, 2010). The importance of team work in the undergraduate engineering curriculum is enforced by the establishment of small teams, with a maximum of 4 to 5 students per team. Each team collectively were required to participate in the practical aspects of the course. The small team size allowed each student sufficient access to topic matter. An assessment was prepared for each of the practical sessions to test the students’ understanding of the relevant SE topic. Assessments included document submissions, group presentations, demonstrations as well as practical activities.

Reverse Order Life Cycle Approach

The Technical Processes definition of the ISO 15288 System Life Cycle standard proposes the Systems Engineering Life Cycle (SELC) to start with Stakeholder Needs and Requirements Definition followed by System Requirements Definition as shown in Figure 1 (ISO/IEC 15288:2008, 2008). In this forward Life Cycle process, component characteristics are deduced from the System Specification in a deterministic process. As students have limited exposure and knowledge relating to design, the progress from system specification to component and system development is difficult to teach.
The teaching of complex engineering can however, be enhanced by following the inductive approach or bottom-up approach to teaching (Meyer & Simpson, 2018). An inductive approach can be used to expose the students to the Reverse Order Life Cycle (ROLC) as shown in Figure 2. The ROLC starts with the already developed and manufactured product from which the underlying components are extracted by physical decomposition.

By following the ROLC engineering V-Model (Forsberg, 2005) approach, students are exposed to an already designed and manufactured product where they are guided to work back to predict the underlying component structure of the product. The System Design Specification is subsequently deduced from the known characteristic or behaviour rules of the components. During this process, the experience, skills and knowledge utilized by the manufacturer during the design and manufacturing of the final product may then be revealed.

In this way undergraduate students with very limited design experience can get exposure to the many facets of engineering knowledge required to design, implement and manufacture products. By guiding the students on this path of discovery, the systems engineering concepts explained in the theory sections of the course are made real to them through the analysis of the already manufactured systems.

Complexity and Budgetary Approach
SE design methodology is well suited for the design of complex systems. However, at undergraduate engineering student level the student’s ability to deal with complexity is not fully developed and students struggle to comprehend complex systems (Wasson, 2004). Students are more often than not overwhelmed by the complexity of systems which then blinds them to the teaching of the fundamental underlying Systems Engineering concepts. To overcome this challenge, the course was structured around an everyday used commercial product. The student’s familiarity of an everyday product allowed them not to be distracted by the complexity of the product since they already have a thorough understanding of the operating principles of the device. Most modern-day household objects contain sufficient interdisciplinary complexity to allow the development of the Systems Engineering concepts underpinning the development of the product.

The demand for engineering graduates in industry have forced tertiary institutions to have large class sizes, up to and exceeding 100 engineering students. Financial challenges in the higher education sector also contributed to constrained teaching budgets which limits the funding available for teaching and learning resources. The limited funding and the large class sizes pose challenges for courses requiring individual student participation in technology applications. The approach followed was therefore to find suitable technology objects of everyday use which could be procured in reasonable quantities without placing unnecessary demands on the already limited teaching consumables budget.

SYSTEMS ENGINEERING COURSE LAYOUT

The SE course was presented to undergraduate electrical engineering students in the third year of study at a Washington Accord (IEA, 2014) accredited engineering education institution. The course was structured to allow the development of basic SE concepts, including System Validation, Systems Architecture, Systems Requirements and specifications, Systems Modelling and Systems Safety.

An ordinary household electric kettle was selected as the technology object of which the underlying systems engineering concepts were studied. The kettle is an everyday object with which all the students were familiar with the operation and function thereof and the costs associated with a standard electric kettle fell within the budgetary requirements of the higher education institution. The kettle is the culmination of different engineering disciplines such as mechanical, electrical and industrial engineering with fundamental electrical and thermodynamic science foundation. Being an everyday object, the kettle must comply with safety and regulatory standards of which the introduction to the students are of importance. The design of the kettle also considers aspects of esthetical design, design for mass production and design for usability.

System Validation

Following the ROLC approach, the first task the students had to perform was system validation. The students had to follow the validation methods of Inspection, Demonstration, Analysis and Test. Each group was given a kettle in the original manufacturer’s packaging. The method of packaging and any instructions regarding the operation and specifications of the kettle had to be identified and captured to be used in the verification process:

Inspection: A visual inspection of the kettle was undertaken to identifying functions, interfaces (electrical, mechanical, human) as well as manufacturing constraints.

Demonstration: System functionality were determined by demonstration as students were required to use the kettle as instructed in the manual.

Analysis: A physical configuration audit was performed on the kettle to establish the design parameters of the kettle, such as water capacity, electrical power consumption and physical characteristics.
Test: The performance of the kettle was validated through testing. The tests conducted included measuring the temperature versus time performance for the heating and cooling cycle of the kettle using a predetermined quantity of water.

All student groups were comfortable to operate the kettle and perform validation tests. Students performed the standard required heating and cooling tests, but also conducted various safety validation tests, for example switching the kettle on without the minimum required amount of water. Results included students realizing that the kW rating of the electric element is not exactly as stipulated on the box and that small variation in the test setup may influence results (different placements of temperature probe, water levels etc).

**System Architecture**

The second task was to determine the system architecture by identification of the system boundaries and the various sub-systems. Each sub-system’s border was identified, examined for energy, material and information crossings to establish the interface specification for that applicable sub-system. A functional architecture diagram was drawn showing how the system is constituted from the sub-systems with the relevant interfaces of the system and sub-systems shown. After the subsystems were determined, the kettles were disassembled into its smallest components. The students had to identify and capture the components in a bill of materials. The relationships between the components and the sub-systems had to be determined. The students then proceeded with the drawing of the wiring schematic of the kettle, where all electrical components in the bill of materials had to be included. The wiring diagram of the kettle was used to demonstrate to the students the relationship between the functional architecture and the implemented architecture.

Students struggled to distinguish between functional subsystems and physical subsections of the kettle. For example, when considering the electric element of the kettle, students struggled to understand the difference between the type of component (electrical) and its functionality (heating). Students wanted to put all electric components into the electrical subsystem (responsible for providing electric power) but failed to realize that some were responsible for heating (element).

With the creation of the sub-systems diagram and the wiring schematic, the students learned that the same type of components may have different functionalities. For example, in the wiring diagram there exists two resistors (element and resistor for the LED), where the element belonged to the “heating sub-system” and the LED with its resistor belonged to the “power indication system”.

**System Requirements**

The third task was to introduce the students to systems requirements. Requirement Management topics such as requirement types, requirement language, attributes of good requirements and requirement specifications were presented to the students. From the System Validation and System Architecture experience the students had gained enough knowledge to derive the System Requirement Specification. The design requirements for the kettle had to be presented in a kettle design requirement specification.

As the students understood the functionality, performance, safety and other aspects of the kettle due to previous practical sessions, the technical aspects of the requirements were not difficult for the students to understand. The theoretical session could focus on the structure of requirement and specification writing and not burdened with technical aspects.

**System Modelling**

The fourth task required the students to develop a mathematical model to predict and simulate the physical operation of the kettle. The motivation behind the modelling of the kettle was for students to gain a better understanding of the factors at play in the system and how various parameters influence the operation of the kettle. A comprehensive model of a physical system allowed the students to:
• Determine whether the desired performance is attainable;
• Determine under what bounds the system operates;
• Determine the most cost-effective means of achieving a desired level of performance;
• Control the system to achieve a desired objective.

The basic steps followed to model the system were:

• Research of the underlying physics;
• Development of a mathematical model describing the system;
• Fit the model to the experimental data;
• Validate the model by determining the acceptability of the modelling errors;
• Perform sensitivity analysis on the primary design parameters.

With the estimated parameters of the kettle and the mathematical model of the kettle the students were required to make predictions of the power consumption and time duration for heating and cooling different quantities of water. Design decision regarding the acceptable performance of the kettle versus electrical power consumption and thermal insulation could be demonstrated by the modelling of the kettle.

This exercise gave students exposure to the importance of systems modelling, but also working across engineering disciplinary boundaries. Students were surprised to incorporate techniques and knowledge from other subjects, such as mathematics and modelling, into the systems engineering subject.

**System Safety**

The final task aimed to expose students to the risk management processes associated with systems engineering involving the identification, quantifying and handling of risk. From the disassembly of the kettle into its lowest components, the students had to analyse each component according to its purpose and how the manufacturer mitigated risk in the design and utilization of that component and subsequently the subsystem and system as a whole. From this analysis the students had to perform a preliminary hazard analysis by identifying all possible hazards of the system. Each identified hazard was recorded, and an associated severity and probability of occurrence classification assigned.

For each hazard, the risk index was determined from the product of the hazard severity index and the hazard probability of occurrence index as dictated by a standard risk matrix. For each identified risk the students had to analyse the design decisions made by the manufacturer to mitigate the risk. As example: the risk of electrical shock to the user of the kettle was identified with a high-risk index. The manufacturer mitigated the risk by using electric isolation of the kettle element, an earth wire, electrically isolated material for the manufacturing of the kettle handle, which effectively reduced the risk index to a low level.

The students followed this method to produce a Risk Analysis document containing the list of identified hazards with its associated risk index and the mitigation procedures the designer and manufacturer have followed to reduce the risk of each hazard to an acceptable level.

**RESULTS: ASSESSMENT OF LEARNING**

After the conclusion of the five learning sessions, students were asked to complete a survey relating to the implementation of the ROLC in the systems engineering module. The survey contained ten Likert scale questions, with possible responses on a 5-point scale ranging from “strongly disagree” to “strongly agree”. The researchers and lecturers of the class structured the questions in the survey in order to determine if the ROLC approach helped the students to understand complex systems engineering concepts and included the following:

Investigating the kettle helped me to understand the principles of SE.

The analysis of a commercial product enabled me to understand and implement the SE process.
The practical sessions enhanced my understanding of the theoretical concepts taught in class.

The small group enabled me to gain hands-on experience which helped me to understand SE concepts.

All the 3rd year undergraduate electrical engineering students registered for the module were asked to complete the survey. In total, 89 students were registered for the course and 40 students completed the survey. The survey was conducted in class after the conclusion of the final practical session. The results from the 10 questions are provided in Figure 3 below.

![Figure 3: Survey results](image)

The results obtained from the survey were favourable for the use of the ROLC approach to teach core systems engineering concepts. The students indicated that the small groups and the utilization of the kettle assisted them to understand systems engineering concepts better.

In addition to the 10 questions, students were asked to provide additional feedback if willing. In the open feedback section three main themes could be determined:

1. The utilization of the kettle as a system
2. The method of group work
3. The importance of safety standards in projects

Many students commented on their surprise to discover the complexities of the kettle. One student stated that “(u)se the kettle had a good standing in terms of simplicity and had just enough complexities to give (them) a good idea of how different system interact...”. A second indicated that he/she “didn’t know a kettle was this complicated” and that the “lessons really taught (them) how to think like an engineer”. Other students stated that “(t)he kettle is a simple device with a complicated design behind it. It was good that to be taught the systems engineering principles using it because one can realise the importance of design and manufacture in engineering” and that the “kettle simplicity helped with gaining the knowledge of system engineering and taught me how it can be applied to more complex systems.”

Students also commented on the group activities. A student stated that he/she “learnt that engineering is a group activity, you need to work together in order to learn new things”. Another commented on learning the “ability to analyse and apply the strengths of team...”
members”. A third student stated that an important lesson learnt was “(t)he importance of team work and communication when doing an engineering project”.

Lastly, students commented on learning more about the importance of safety standards when designing. Students stated that “safety needs to be considered with a project/product because the first duty of an engineer is the health and safety of the public” and that it is important to “apply safety standard to the project / product(s)”. Results from this study show that the students’ familiarity of the everyday product allowed students not to be distracted by the complexity of the product since they already have a thorough understanding of the operating principles of the device. The electric kettle contained enough interdisciplinary complexity to enable the student to develop and understand the systems engineering concepts underpinning the development of the product. Overall, most of the students indicated that the method of instruction assisted them in learning systems engineering concepts and gave them a fair understanding of how complex systems interact and function.

CONCLUSION
This paper presented a reverse order life cycle approach for enhancing systems engineering education in an undergraduate programme in electrical engineering. An ordinary electric kettle was selected as the technology object of which the underlying systems engineering concepts were studied. Utilising the reverse order life cycle process, students used inductive reasoning by observing the final product (electric kettle) first and predicting the underlying component structure of the product. The learning experiences of the students were captured through individual reflection reports as well as group feedback.

The study indicates that the use of the reverse order life cycle process enabled the students to grasp and understand the concepts of systems engineering in a real complex system. Through inductive reasoning by observing the final product, students could see the experience, skills and knowledge utilized by the manufacturer during the design and manufacturing of the final product.

As industry and government become more dependent on systems solutions for complex problems due to the advancement of Industry 4.0 technologies, the students’ understanding of complex systems and the systems engineering concepts underlying these systems are critical. The utilisation of an electric kettle, where the technical functions are well known, enabled the engineering lecturer to provide expert insight and guidance regarding the SE concepts are they were taught to the students. As the studied system was familiar, the students could gain the necessary insight and understanding regarding the dynamics of a complex system and the underlying systems engineering concepts.

The results of this work show that the use of the ROLC process and a familiar electrical appliance, such as an electric kettle, can better prepare students for future SE jobs as it improves undergraduate students’ understanding of real-life complex systems seen in society today.

REFERENCES


ICT EDUCATION PAPERS
RURAL LEARNERS’ PATTERNS OF ENGAGEMENT IN SYNCHRONOUS ONLINE MENTORING GROUP CHATS TO ADVANCE CONCEPTIONS OF CAREER DEVELOPMENT

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ABSTRACT – Learners in the rural settings are deprived of necessary support mechanism (mentorship, motivation and guidance) for career consciousness and lack sufficient exposure to diverse careers. This study reports on an online-based mentoring programme designed to expose learners to multiple mentors from distinct career fields, institutions and occupations. The online mentoring program was conducted through regular WhatsApp group chats in which mentors (identified as guests) engaged with learners in sharing their social and personal backgrounds, career history and advancement. A group of 35 learners participated in the intervention and data comprised of activity logs of conversations. These were analysed using the Exchange Structure Analysis (ESA) model, and codes were generated pertaining to instances of orientation. The emergent interactional patterns suggest that in greater open and informative conversations, learners benefit from online mentors who assume roles of mediators between unique careers and the real-world situation. These interactional patterns further suggest that synchronous conversations with rural learners need to comprise of more teaching exchanges and less boundary exchanges to allow informal and spontaneous flourishing of conversations. Recommendations for good practice are emphasized for educators striving to narrow the knowledge gap between the learners in disadvantaged and advantaged settings through digital media.

Keywords: Rural learners; career development; synchronous mobile group chats; mentoring

INTRODUCTION

Career guidance is still not given substantial attention in schools and career choices is generally informed by knowledge of more traditional careers such as teachers, nurses, and social workers (Nong, 2016). Not being familiar with alternative careers diminishes learners’ optimism to succeed and limit their career perceptions. According to Nong (2016), career guidance and support are crucial in the country’s education system to ensure learners’ holistic and active participation in the socio-economic growth of South Africa. Urban learners, outside of their school environments enjoy far more exposure to alternative careers opportunities compared to rural learners. Assisting greater knowledge of career opportunities necessitate access to mentors and role-models. Moving from traditional modes of mentoring typified by face-to-face interactions to more online-based mentoring is inevitable in modern day educational pursuits due to the rapid advances in the affordances of Information and Communications Technologies (ICT). Traditional mentoring models are gradually being re-structured to fully exploit the affordances of new technologies placing the rural learner is in a favourable position to directly benefit from increased access in a non-traditional modes of mentoring. This article aims to provide some insight into how rural learners can possibly be mentored through using social media in the form of synchronous mobile group chats to gain access to and engage with skilled career professionals (acting as mentors) to shape their conceptions of career development.

BACKGROUND OF STUDY

In the past, the word mentor was associated with senior individuals taking the role of guiding protégé. Traditionally mentoring is conceptualized as a dyadic relationship in which the mentor, the senior person in age or experience, provides guidance and support to the less experienced person, the protégé (Hunt & Michael, 1983). Mentoring was limited to face-to-face relations in which the mentor, an experienced person was assigned a role to guide and support the novice protégé (Hunt & Michael cited in Ensher, Thomas & Murphy, 2001). On E-mentoring for career development, Gross (2012) observes that the traditional role of a mentor in a workplace is intended to assist new recruits to learn the dynamics of the working environment. The traditional definitions seem to limit mentorship to face-to-face relations, thereby only accommodating protégés who are physically capable of interacting with
mentors. This marginalizes geographically isolated potential protégés. Politically and traditionally, mentoring in education perpetuates social inequalities by affording mentoring opportunities only to advantaged protégés. The role of a mentor is to provide professional guidance in a working environment. Gross (2012) mentions that a mentor was regarded as a “teacher, guide and father figure” who took the responsibility to advise the protégé. The historical perceptions are restrictive and they assume that only older members (the father figures) can be mentors.

From the traditional perspective, the mentor-protégé relations had its orientation towards the mentee benefiting more from the relations than mentor did. The mentor served as an authoritative figure, or rather dispenser of knowledge. In contrast, Freedman (1992) and Shea (1994) argue that mentor-protégé relationships are reciprocal. The role of a mentor in the reciprocal relationship is to socialize the protégé into the norms of the organization, thereby increasing organizational communication and commitment (Ensher, Thomas & Murphy, 2001).

Due to greater changing needs and expectations in occupational environments, Burlew (1991) suggests that protégés utilize multiple mentors throughout their careers. This is also supported by Thomas and Higgins (1996) who accentuate a greater need to access a diverse network of mentors. Accessing diverse mentors (making reference to traditional model) would be only convenient to protégé living in context conducive for direct physical networking. This further creates a knowledge or a career guidance gap between protégés in urban and those in disadvantaged territories. Hence, the emergence of e-mentoring, online mentoring, and digital mentoring.

Although the term online learning has existed for a long time, it still faces greater challenges against direct generic definition. At times, it is used interchangeably with other terms such as open learning, networked learning, virtual learning and e-Learning (McPherson & Nunes, 2004: 19). Regardless of the multiple synonymous terms used to describe online learning, McPherson highlights that all terms have common characteristic, that is, computer-mediated instructional method as opposed to face-to-face traditional methods. In earlier definitions, before the advent of Web 2.0, online learning referred to the learning and other supportive material available through a computer (Carliner, 1999). In another definition, (which linguistically seems contradictory), Carliner (1999) in the glossary defines online learning as educational material that are presented on a computer. A dilemma arises between deciding whether online mentoring is a process or a type of learning, or in essence, material for learning. Furthermore, Carliner (1999) also indicates the confusion and complexities revolving attempts to define online learning by highlighting that computer-based training, web-based training, computer-based instruction and technology-based instruction are wrongfully utilized interchangeably with online learning. Essentially, these terminologies are forms of online learning and have distinct meanings (Carliner, 1999). In light of the multiple definitions of online learning in this research, I shall refer to it as learning taking place through internet-based medium. This suggests that without internet, there would not be online learning.

Online participation and socialization has improved significantly in the recent years. The advent of smartphones and ubiquitous spread of social networking tools have made it easier for individuals, regardless of their geographical settings, to connect with each other. In fact, social media has altered the way information circulates in users’ cultures (Poore, 2013). The media includes tools like blogs, wikis, YouTube, Twitter, Instagram, Facebook, and WhatsApp. In view of the general qualities and characteristics of social media, Poore (2013) asserts; community-building, participation, interactivity, flexibility, sharing and networking, are significant in online mentoring programs. Facebook and WhatsApp applications among South Africans are the most utilized forms of social media (World Wide Wax and Fuseware, 2014).
WhatsApp is a more instantaneous messaging tool compared to Facebook which requires users to log in for delivery of messages. Bouhnik and Deshen (2014) report that WhatsApp, as a synchronous instant messaging application, embraces user friendliness, cost efficiency, availability and instantaneity of delivery of messages. Similarly, Beltran-Cruz and Cruz (2013) report that WhatsApp has educational advantages such as, creating “pleasant environment and in-depth acquaintance” which results in positive influence on the nature of conversations. Research on the use of WhatsApp in Higher Education and Training Institutions, find that the application enhances accessibility, cooperation and maximises motivation to actively engage others on educational projects or assignment (Rambe & Chipunza, 2013). WhatsApp as a widely accepted and an accessible application, it therefore ideal to assist rural learners to exploit the affordances to enhanced learning as listed earlier.

Due to remote and isolated rural geographic locations, learners in rural schools are generally deprived of career guidance when compared to their counterparts in urban areas (Nong, 2016). Considering the capabilities of social media in expanding, widening and reinforcing social interactions (Sooryamoorthy, 2017), rural learners in particular have much to gain from access to this extended information stream. Gaining insight into how rural learners can possibly be mentored through social media in the form of synchronous mobile group chats can inform our understanding of how they shape their conceptions of career development. Engaging directly with skilled career professionals (acting as mentors), can go far in assisting rural learners in learning more about new career opportunities as well as deepen their understanding careers they are more familiar with.

METHODOLOGY

This descriptive case study uses a qualitative research approach. The research scrutinizes the case of a grade 11 and 12 science learners in a secondary school located in a rural village in northern Limpopo. On a weekly basis, approximately 35 learners of both genders engaged in career development social conversations through WhatsApp group chats with professionals that stem from similar rural areas, but have gained prominence in various careers.

The mentors vary in that they have different levels of study, areas of specialization, occupations and are from different educational institutions. Mentor 1, Charmaine is a biomedical scientist specialising in Molecular Medicine, Immunology and Infectious Diseases (molecular medicine and Tuberculosis) in her early 30s and she has been a researcher for more than 5 years. Mentor 2 was disguised under the name, Chantel. She is an astronomy expert in her early 50s and has been in the industry for more than 15 years. Mentor 3, Mudhi is a mechanical engineer and have contributed to the development of University of Johannesburg’s solar car. He is in his late 20s and has been an engineer for more than 2 years. Mentor 4, Koki is in his mid-20s and studied Organic Chemistry and has been employed for a year.

In this intervention, their role as mentor is to narrate their career journey, and describe the nature of their studies and occupations. During this time, learners can pose questions and engage in digital chat conversations with each other as well as with these mentors to learn more about their particular career. These interactions are scheduled to last between 90 to 240 minutes at a time.

From the weekly or bi-weekly recorded online mentoring conversations on career guidance during the semester, a sample of four separate activity logs with sustained (or longest) duration of social exchanges were selected and analysed. This purposive sample ensures that only data with rich information central and relevant to the purpose of the inquiry are examined (Yin, 2006; Patton, 2015). The five samples of weekly conversations were analysed using the Exchange Structure Analysis (ESA) coding scheme (Kneser, Pilkington, & Treasure-Jones, 2001). Data for the synchronous activity logs was analysed and coded with the aid of Exchange Structure Analysis (ESA) model. This model is employed due to its “widespread use, simple coding technique, and for current and future comparisons" nature.
(Wishart & Guy, 2009). Having made references from Sinclair and Couthard’s (1992) transactional analysis as aforementioned; Kneser, Pilkinson and Treasure-Jones (2001) developed an adapted ESA model that this study embraced in order to investigate the nature of turns in synchronous online discussions. Data was coded in two significant categories: Exchange Structure (ES) level and Move level (ML). The ES level unveils the structural organisation of the pedagogical chat exchange while ML analysis indicates the communicative intentions underlying the turns constituting the exchange (Lim, 2006).

In ESA, Dawes (2004) identified ‘Initiate Response Feedback’ (IRF) as a mechanism to analyse conversations to establish interactional patterns. IRF codes denoting exchanges (turns) and moves (speech acts) as captured in the synchronous WhatsApp group chats conversations, are assigned to each exchange between rural learners and weekly mentors that speak to career development. Once different types of exchanges have been identified and coded, a count of the various codes is used to check the different types of “turns” during these learner-mentor exchanges. Although the study is qualitative, some descriptive quantitative data will be used to identify frequencies of exchange types, move levels, elements of Exchange Structure (ES) levels and Off-Topics (OT). The aim is to establish interactional patterns and then describe how learner conceptions around career development are formed.

RESULTS AND DISCUSSION

Pseudonyms for mentors and learners are used to adhere to acceptable ethical standards. Each data set was analysed for exchange types, elements of ES level, move level and off-topic turns and against frequencies. The next stage of data presentation and analysis comprises of comparison between all four mentors’ data sets. It depicts how each mentor scored against others with regards to different layers of ESA model of results. An overall comparison and analysis of the data sets is provided in Table 1 according to different categories guided by literature on ESA model.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Categories and patterns</th>
<th>Charmaine</th>
<th>Chantel</th>
<th>Mudhi</th>
<th>Koki</th>
<th>TOTAL</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exchange types</td>
<td>TE (Teaching Exchange)</td>
<td>246</td>
<td>188</td>
<td>171</td>
<td>88</td>
<td>693</td>
<td>88</td>
<td>246</td>
</tr>
<tr>
<td></td>
<td>BE (Boundary Exchanges)</td>
<td>19</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>29</td>
<td>3</td>
<td>19</td>
</tr>
</tbody>
</table>

Table 1: Overall counts in all mentor data
The overall analysis of data as depicted in Table 1, shows that Charmaine had the highest number of turns as compared to others. She had 784 counts against Chantel, Mudhi and Koki who had 611, 504 and 284 respectively. Charmaine scored the highest on the TE (n=246), RC (n=105), FBK-A (n=74). She also had numerous counts on RI, FBK-E, INF, EXD,
JUS and OT-S. The mentor with lowest frequencies on majority of levels was Koki, the analytical chemist.

It is also evident that teaching exchanges among all mentors were at greater frequencies than boundary exchanges. For Chantel, Mudhi and Koki, boundary exchanges frequencies were almost closer to none. All mentors scored highest on Teaching Exchanges (TE). This suggests that more of the online conversations in the WhatsApp group constituted the asking of questions and provision of feedback (Cockayne, 2010). The highest frequency having emerged from Charmaine and Chantel hierarchically provides that these mentors were more open to initiating conversations throughout the exchange. Lower counts of BE signifies less mentors’ contribution towards signalling learners to move from one section of the conversation to another. Transitions from sections occurred spontaneously.

It is important to note that all conversations comprised of frequent counts of acknowledgment, feedback or evaluation and responding turns. The higher output of frequencies under RC, RI and R among all mentors conveys that learners more responsive and comfortable with continuation of a turn from another participant that initiating their own. It is not astonishing because initiation moves are normally made by the teacher (Hellerman, 2003), who acts as a mentor in this study. This output could be attributed the mentors’ career fields and how the fields were elaborated authentically. Charmaine narrated her personal background to the learners and has grown up from the same area as the learners. Learners related to her background constituents such as losing her parents at a young age, growing up in unstable households with relatives and developing illnesses at the age of 11. Furthermore, Charmaine’s career journey is based on familiar illnesses like tuberculosis. This is related to what learners experience at home and it is also curriculum related under Life Sciences in high schools. Hence, learners responded with great interest during the interactions. Chantel’s career is not typical to the learners. Astronomy career is frequently seen in the movies and scientific books. Hence, interacting with an expert elicited a lot of interest from the learners. This is also because of how Chantel made the mentorship authentic - how astronomy related to the real life experiences.

Comparing all move levels, there were less reasoning, justifications, clarifications and extensions across all mentor data sets. FBK-A, FBK-E and INF have dominated the conversations. Pilkington (1999) and Lim (2006) describe that the INF move is characterized by provision or description of information or event whereas FBK-A and FBK-E report on the state of the participant and acknowledge understanding of the turn, and validity of correctness of the previous turn. In essence, learners limitedly inquired, sought clarity, justification or extensions from mentors or otherwise. This could either be an indication that prior guidance that was provided to mentors by the administrator was useful such that adequate information was provided to the learners, or that the rural learners were amazed by the unfamiliar careers and hence acknowledged understanding. The amazement could also be proven by the higher frequencies of RC.

Lower frequencies on, CLA, JUS and REA can be attributed to the lack of questioning during the interactions. The WhatsApp intervention was set up in such a way that mentors were briefed on the structure of the group to provide background, talk about the nature of their careers and respond to learners’ turns (either questions, comments or request). Question and answer sessions required a different setup; it was aimed at eliciting information more than merely career field exposure.

Off-Topic turns emanated from WhatsApp data sets from all mentors. Chantel’s conversations were greatly characterized by OT-A, with very less reflecting on Koki’s data set. This can be attributed to more administrative (housekeeping) issues exchanged during Charmaine’s interaction. Examples of such OT-A may be the frequent “pinging” and assessment of satisfaction and understanding during conversations. Charmaine had the highest score on OT-S. This means that Charmaine exchanged important social turns that kept the online group conversations going. This is probably one of the reasons the learners
were more open to Charmaine and Chantel more than the others. Hence, higher total number of conversation entries in the data logs. Lower frequencies of OT-S on Mudhi and Koki may be attributed to gender. Males generally do not portray social elements as much as females during conversations. The lower frequency on Koki’s OT-A is attributed to the readiness of the learners ahead of the WhatsApp engagement. There were very limited housekeeping issues. All mentors interacted with the same group of learners throughout the mentorship program.

Overall comparison Figure 1, provides a brief summary of the overall ESA level group categories against all mentors. All data that was presented individually against every mentor in the previous discussion are brought together for holistic comparison. The following figure 1, places mentors against all ESA levels: TE, BE, RI, I, R, RBK-A, FBK-E, INF, EXD, CLA, JUS, INQ, REA, D, OT-A and OTS.

**Figure 1: Overall comparison of ESA level categories of mentors**

The results presented in Figure 1, portray that Charmaine and Chantel had the highest counts of interactions with frequency of 784 and 611 turns respectively. It is notable that these mentors are all females, against their male counterparts; Mudhi and Koki. Hmelo-Silver, Jeong, Faulkner and Hartley (2017) assert that in computer mediated platforms there may be emergence of unforeseen gender effects such as communication gaps in knowledge elaborations. In this study, the two female mentors had higher frequency outputs on almost all patterns of communications. This means communication gaps in elaborations of career guidance between learners and the female mentors were not as narrow as it is depicted in interactions with the male counterparts.

The assertion concurs with the findings that social conversation enhances (OT-S) such as greetings, social banter and emoticons (Lim, 2006) reported significant emergence on the data logs of Charmaine and Chantel. These OT-S turns support development of social interaction, hence, yielding higher output of turns which lead to prolonged conversations.
(Lim, 2006). ESA level group categories yielded lowest frequencies were D, REA, JUS, CLA, I and BE. Moreover, the setup of the group did not afford opportunities for learners to initiate conversations as mentors were briefed by the administrator ahead of the chats. Part of briefing required that upon being added onto the group, mentors should introduce themselves, and provide a brief background and can account for the low I count. Also, conversations were not formally structured. They transitioned from one section to another naturally, hence lower frequency on BE. Since the main intention of the intervention was to enhance career conceptions of the rural learners, there was not much opportunities for question and answer sessions resulting in limited EXD, CLA and JUS.

CONCLUSION

Learners enjoy online mentors, who should assume the roles of mediators between unique careers and the real-world situation. This affords learners an opportunity to want to learn more in order to enhance their career conceptions. These patterns further suggest that synchronous conversations with rural learners needs to comprise of more teaching exchanges and less boundary exchanges to allow informal and spontaneous flourishing of conversation.

Synchronous online mentoring mobile group chats can therefore advance rural learners’ career perceptions by affording opportunities for spontaneous informative communication between mentors and learners. The nature of the intervention is enhanced by frequent social conversation enhancers (OT-S) throughout the chats so that learners feel comfortable to interact with mentors. Interactional patterns that emerged were mainly informed by mentor-learner relations, the nature of conversation and the gender of the mentor. This study contributes to our understanding of how to go about supporting rural education through the use of social media such as WhatsApp in order to ensure that rural learners receive access to mentors and role models to further advance their conceptions of career enhancement.

REFERENCES


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ABSTRACT – The aim of this study is to explore teachers’ reflections on the use of learning technologies in inclusive education that is, in a school of learners with special educational needs (LSEN). We argue that steady progress has been made to enhance inclusive education in schools over many years towards educating more children with special educational needs in mainstream schools, particularly children not only with demanding learning difficulties but physical, mental and sensory handicaps. By the same token, learning technologies are being introduced and accepted in diverse educational contexts, offering opportunities for innovation and for making learning processes more encompassing, engaging, and collaborative and above all, making the learning content more accessible for learners with learning disabilities. However, though learning technologies have been introduced and accepted in diverse educational contexts, little has been reported on teachers’ reflection in and on the use of learning technologies in inclusive education, in Gauteng Province, West District. This enquiry employed a qualitative case study to capture six teachers’ reflections in the use of learning technologies in inclusive education through observation, focus group interview, individual interviews and documentary sources. The collected data was analysed inductively through the theoretical framework of reflections. Results showed that teachers adapted the mainstream learning technologies curriculum to the level of learners who had positive learning experiences with technological tools. On the other hand, teachers acknowledged that they need professional development in the use of learning technologies in inclusive education.

Keywords: Information and Communications Technology, inclusive education, learning technologies, learners with special educational needs, reflection

INTRODUCTION

Dewey (1910) defined reflective thought as: “active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends” (pp.6). Thus, reflective practitioners are teachers who can question themselves, reflect on their practices, build new pedagogical techniques when needed, and develop their expertise using continuously-acquired knowledge of the profession (Kayapinar, 2018). Pillay and Terlizzill (2009) contend that learners’ learning difficulties or disabilities stem from poor focus and concentration, below average concrete and logical reasoning, poor fine motor skills as a result of low muscle tone, problems associated with visual perception and auditory discrimination, as well as a low self-esteem and social difficulties. Thus, the use of learning technologies in the classroom by teachers can make significant differences to life experiences of their learners and including those who are experiencing learning difficulties in the learning process (Dikusar, 2018).

BACKGROUND TO THE USE OF LEARNING TECHNOLOGIES IN INCLUSIVE EDUCATION

Inclusive education has the potential to improve learning outcomes of LSEN. These learners have varying cognitive, physical, emotional, and behavioural learning needs. They demonstrate diverse abilities and academic achievement (Kang & Martin, 2018; Szczytko, Carrier & Stevenson, 2018). In support for LSEN, the South African Department of Education (DoE, 2001) drafted a White Paper 6 on Inclusive Education to accommodate all learners with learning disabilities in schools. The justification of the White Paper 6 on inclusive education and training is to: (i) acknowledge that all children and youth can learn and need support; (ii) acknowledge and respect differences in learners while building on similarities; (iii) foster attitudes, behaviour, teaching methods, curricula and learning environments that meet the needs of all learners, and (iv) uncover and minimise barriers to learning.
The main objective of any education system in a democratic society is to provide quality education for all learners, including those with physical, mental and socioeconomic challenges, so that they will be able to reach their full potential and contribute meaningfully to society throughout their lives. According to Landsberg, Krüger and Swart (2019), everyone has the right to education. South Africa has adopted an inclusive education policy in order to address barriers to learning in the education system. Similarly, inclusive education is seen as a process of addressing and responding to the diversity of needs of all learners through increasing participation in learning. It involves changes and modifications in content, approaches, structures and strategies, with a common vision which covers all children of the appropriate age range and a conviction that it is the responsibility of the regular system to educate all children (United Nations Educational, Scientific and Cultural Organization, 2005; British Educational Communication and Technology Agency (Becta), 2007). However, the implementation of this policy is hampered by the lack of teachers’ skills and knowledge in differentiating the curriculum to address a wide range of learning needs (Dalton, Mckenzie & Kahonde, 2012; Conway, 2017). Therefore, in order to support teachers in the implementation of inclusive education, the South African DoE (2004) drafted a White Paper on e-Education which upholds that every South African learner should have access to the use of Information and Communications Technology (ICT)/learning technologies. These concepts, ICT/learning technologies are used interchangeably in the context of this study.

Other ICT policies include guidelines for teacher training and professional development in ICT (DoE, 2007), Gauteng Online ICT laboratory access (2005) and Circular 71/2008 for the integration of digital assets for teaching and learning (Gauteng Department of Education (DDE), 2008). All these policy documents are to leverage the learning technologies so as to improve learner outcomes and overcome some challenges that are known to exist and to identifying which teachers are in need of pedagogic assistance in Basic Education (Meyer & Gent, 2016). As a result, learning technologies have the potential to be valuable sources of knowledge, helpful teaching tools and motivators of learning for both teachers and learners in the classroom (Maré, 2019). Fransson, Lindberg and Olofsson (2018) and Maré (2019) report that technologies like Microsoft package (PowerPoint, MSWord, Excel, or Access), videos and sound files; tablets, smartboards, can be linked to computers, projectors and to the cloud so that learners and teachers can communicate through text, drawings and diagrams. Additionally, the GDE introduced smartboard (paperless) classrooms with a view to use mobile devices, such as tablets, to transform teaching and learning in the province (Sekhonyane, 2015) and certainly to keep learners engaged in their learning process (Pilane, 2017). However, teaching with learning technologies in inclusive education is a complex issue as teachers lack the necessary skills and knowledge to teach with them (Fernández-Batanero, Sañudo, Montenegro-Rueda, & García-Martínez, 2019; Hannaway, 2019). On the other hand, Lersilip and Lersilp (2019) argue that teachers need to reflect on their teaching practice in order to find a way of teaching with learning technologies in their teaching practice.

This study uses reflections as a theoretical framework in the interpretation, understanding and challenges teachers faced in teaching with learning technologies in inclusive education. The reflection is defined by Dewey (1938) as a performance of an individual where one actively and consistently involves in contemplation of related experience and practice to make it more meaningful and successful. For Schön (1983) reflection is the element that turns experience into learning. This concept has been acknowledged as important element of effective teaching and it was from that continuing conversation that the term “reflective practitioner” emerged (Schön, 1987). Accordingly, reflective practitioner is someone who actively engages in thinking about teaching with the express intent that reflections about those experiences to inform future practice (Arslan, 2019). There are different dimensions of reflective practice, consistent with Schön (1983), reflection on-action is a reflecting on how practice can be developed, changed or improved after the event has occurred and reflection-in-action is reflecting on the situation while changes can still be made to affect the outcome, rather than waiting until a later time to reflect on how things could be differently in the future.
Critical reflection is another type of reflection that is defined by Mezirow (1997) as a transformative learning in that we are encouraged to view learning as a process of becoming aware of our own assumptions and revising them. Cranton (2002) purports that critical reflection is “the means by which we work through beliefs and assumptions, assessing their validity in the light of new experiences or knowledge, considering their sources, and examining underlying premises” (p.65) in the teaching practice. However, though there are different types of reflections in teaching practice, Tajik and Ranjbar (2018) observe that teachers do not see the value of reflecting in their own teaching practice. From the backdrop of teachers lacking skills and knowledge of implementing inclusive education and how to teach with learning technologies, the research question this study is addressing is: What are the teachers’ reflections in the use of learning technologies in inclusive education? Therefore, aim of this study is to explore teachers’ reflections in the use of learning technologies in inclusive education.

**METHODOLOGY**

This study employs a qualitative case study research design that involves an intensive and holistic examination of a contemporary phenomenon in a real-life setting (Yin, 2014). A case study is used to explore, describe or explain a single case bounded in time and place (Creswell & Poth, 2018; Swanborn, 2010). The case in the context of this study is to explore teachers’ reflections in the use of learning technologies in a school of learners with special educational needs in the West Rand District in Gauteng Province. The school has computer laboratory provided by Gauteng online laboratory project (GDE, 2005). There are a total of 15 staff members in the schools and six teachers were purposefully selected in this case study based on their experiences in the teaching of LSEN. Learners at the school range from the Severely Mentally Handicapped (SMH) to the Mild Mentally Handicapped (MMH), terms that emanate from medical reports which learners bring to the school as an admission requirement. All learners had been referred either by the Medical staff or the District Based Support Team (DBST) from the Education District Office. A learner profile is then devised in which barriers to learning are specified, then the level and nature of support is identified to formulate a support plan.

**DATA COLLECTION**

A semi-structured focus group interview with six teachers was conducted in order to gain an in-depth understanding of how they reflected in their teaching practice when using learning technologies in accommodating LSEN. Two teachers who participated in the focus group interview were further asked to participate in individual interviews in order to elaborate further on how they reflected in their teaching practice when using learning technologies in inclusive education. Observation was used as a method of data collection and six teachers were observed how they used learning technologies for LSEN in the laboratory. Documentary sources that are relevant were used to describe the case of how teachers used technological tools to support LSEN and for their professional development.

**DATA ANALYSIS**

This study used a qualitative content analysis as a method for systematically describing the meaning of collected qualitative data (Schreier, 2012). This method is used for the description and interpretation of textual data using the systematic process of coding by assigning successive parts of the collected data to the categories and sub-categories (Assarroudi, Nabavi, Armat, Ebadi, & Vaismoradi, 2018) according to a theoretical framework of this study. The analysis is done as a way of answering the research question.

**RESULTS**

The research question this study is answering is: What are the teachers’ reflections in the use of learning technologies in inclusive education? In order to answer this question, this inquiry uses teachers’ reflections as a theoretical framework (Schon, 1987) to interpret and
understand the challenges teachers faced in teaching with learning technologies in inclusive education. Accordingly, the established categories within the reflection framework are discussed below.

Teachers reflected on-action and in-action that the learning technologies policies are not implemented by the school leadership and management

Teachers reflected on-action (that is, on the current situation that could be changed or improved) and reflected in-action (that is, in the current situation and what could be changed or improved in the future (Schon, 1987). However, in the context of this study, it was evident that the leadership and management structure of the school were not using learning technologies policies in the teaching and learning as envisaged by teachers. One of the teachers from individual interviews acknowledged that the school was not using ICT policies, indicating that: "Policies in ICT are in place but we use policies in LTSM (Learner Teacher Support Material) and not policies of ICTs for teaching and learning". This comment by this teacher is corroborated by another teacher that: "yes, no ICT policy is used for teaching and learning". Management and leadership have not formulated a clear strategy or a timetable for both the teacher sand learners to have access to the computer laboratory as stipulated by policy document of Gauteng Online ICT laboratory (2005). One teacher reflected that when she has to have access to the laboratory: “…you have to wait so you can take your learners to go down there to the computer laboratory”. This teacher’s reflection shows that teachers limited access when they have to take learners to the computer centre (Navsaria, Pascoe, & Kathard, 2011). Regarding encouragement by the management to integrate learning technologies into learning and teaching, another teacher reflected that that: “There is not enough support, each and every individual will have to see to it, out of your own you have to see how you’re going to integrate, you have to make your own initiative only because, it’s not only that we are going to use as a resource”. A lack of support can be attributed to the lack of vision amongst the leadership and management structure of the school to develop ICT policies that support the use of ICT tools for achieving educational goals (Sangrà & González-Sanmamed, 2010).

Teachers reflected in their teaching practice that they adapted the mainstream ICT curriculum to the level of learners with special educational needs

Teachers’ reflection is viewed as a necessary tool to develop and sustain responsive instructional practice to accommodate the needs of their learners (Wenner, 2017). Unfortunately, the school did not have the ICT curriculum, and in answering this question: Do you have a special curriculum for LSEN? One teacher responded: “No”, and in adapting the mainstream ICT curriculum another teacher from focus group interview confirmed that: “Yes it is adapted”. To be able to modify or adapt the pedagogical approach, teachers are encouraged to employ new teaching method using ICT (Martínez, 2011). However, this presented a challenge as they have to modify their approach. One teacher reflected that: “If you struggle with a curriculum, I mean let alone the integration of the ICT. Can you imagine what is happening, it’s a serious challenge”. Another teacher corroborated what had been said by her colleague about the struggle they experienced when teaching LSEN: “There are different kind of disabilities, one with involuntary movement, arthetoid, cannot even type because his hands are shaking all the way. Some who are partially sighted, whereby we do not have the Braille computers”. Despite the challenges teachers used available ICT tools, as reported by one teacher: “…some pictures and specific programmes, Microsoft Word for that PowerPoint" in the teaching and learning process. Another teacher pointed out that the use of available ICT tools can meet and improve learners’ skills in the use of digital resources: “…you have learners who are able to comprehend (MMH) what you are teaching them but they cannot put it on a written page. And you know I think ICT tools provide for us a way of adapting the curriculum, to reach the through different means of methods. So, I think ICT are the best, if we can get different programmes". Teachers’ reflection in adapting and using available ICT tools to teach learners is supported by Lersilp and Lersilp (2019) that adapting
ICT tools to the instructional activities of the learner will make them to perform in the classroom.

Critical reflection enabled teacher to reflect on your own limit of ICT skills in the teaching activities in the classroom

Critical reflection provides opportunities for a teacher to question himself/herself on aspects one would rather not see or know so as to reach higher levels of thinking and action and to recognise one’s lack of abilities and competences. Furthermore, it provide the basis for individual and group empowerment (Mezirow, 2006). The use of ICT in the classroom should support and enhance learning, teaching and inclusion, and despite the lack of teachers’ competence and ICT skills, learners were able to complete the activities. One teacher confirmed that: “… they work with this thing to get to the end product. I think it works well they can draw they can insert, they can even print, looking at what they have done” (Circular 71/2008). The confirmation that learners can use ICT tools to complete the activities was supported by her colleague: “Yes, on the ICT there are some who benefit because some are fresh from the mainstream, and because of being slow learners sort of, so now when they come here they are working with their own pace”. Teachers reflected that the use of ICT tools can support learners who are under-achieving: “I think it can be used more especially in the LSEN school because we have learners who are able to comprehend what you are teaching them but because they cannot put it into writing, because of in a school of LSEN, fine motor skills are not yet developed. With the use of the keyboard or mouse they can be able to give you the correct answer”. Teachers were aware that any ICT tool that is available can be used to support learners in accomplishing their learning activities. One teacher from individual interviews pointed out that learners were struggling with skills in the learning process in that: “our learners are struggling from reading, writing, understanding communication, all those things”. Mezirow (2006) and Morrow (2011) conclude that when teacher use their critical reflection to transform their teaching practice, their limited skills and competence can be used to introduced to a new method of learning in the classroom.

Through critical reflection teachers reflected that they need professional development to use ICTs in inclusive education

Critical reflection is both systematic and rigorous in the reflective practice as it is essentially from an epistemological discourse perspective, focusing on reflection as a way to understand what we do (Hickson, 2011). In expressing this view about reflecting as a way to understand what teachers do and need in the use ICT in teaching practice, one teacher from the focus group interview reflected that: “From my development plan, ICT was amongst the list of the things that I have requested, but requested workshop about learners with educational needs, am still waiting for those particular training as I’ve requested”. Teachers also pointed out the need to identify the type of professionalism required in the use of ICT for their school, for example: “…most of the workshops that we got only comes from the district, …. type of programme that do not fit for our school”. ICT can be an effective tool in supporting teaching practice and teachers were given laptops. However, one from individual interviews teacher said: “giving us the laptops to try something. So I did not get the support that I expected from you as well, so I did not go anywhere because I felt frustrated. I really wanted to try that but I felt frustrated because it was so complicated”. An important element in teachers’ professional development is the quality of support and training they receive in terms of planning, implementation and reviews. Fook and Askeland, (2006) confirm if teachers can reflection and be able to analyse their assumptions in their teaching practice, they will see the value of professional development in the use of learning technologies.

Critical reflection enabled the teacher to reflect on the need for professional support in addressing their attitudes towards ICT in their teaching practice

Leadership and school management must take the lead in creating a vision that motivates and changes teachers’ attitude towards teaching using ICT tools. Critical reflection could be thought as a process of thinking about the conditions for what one is doing and the effects”
(Steier, 1991, p.2) and about their own assumptions or attitudes and that can be revised (Mezirow, 1997). During the interview one teacher raised the view that: “You know training in itself is not the only way, because it is also about the individual attitude of the educator. I would say change is not easy, how do we change the attitude of an individual? You can't, some are just afraid. If you could call a meeting and ask what is your greatest fear, they know but what is in them does not change, even teachers have barriers, I would recommend counselling of teachers”. On probing as to whether teachers have an attitude towards the use of ICT tools in the classroom, another teacher responded: “Yes they have an attitude, they have a well-developed negative attitude towards the computer lab. Because maybe they think, or they undermine themselves for their knowledge that they have”. Support and proficiency in the use of ICT tools by teachers can help them overcome their fear, as indicated by one of the teachers: “…maybe if they would know how computers works or how ICT makes their lives easy teaching is very simple with computers and that can change the attitude”. Another from focus group interview added that support for teachers “…will also eliminate the fear of educators who are ... afraid to go there because of the fear of the unknown”. According to Umugiraneza, Bansilal. and North (2018), if teachers are supported in the use of ICTs, they develop positive attitudes towards them in the teaching and learning processes.

Teachers reflected that the timetable structure of the school limit them to access the use of ICT resources for teaching and learning

The GED (2005) schools for LSEN are allocated special budgets to procure ICT, making it possible for teachers to access various forms of currently available technology. The availability of ICT resources was confirmed from individual interviews by one teacher: “…we have laptops, Mimiopads, overhead projectors, the white boards, video cameras, digital camera”. Despite the availability of ICT tools, teachers have limited access to the computer lab as a result of the school’s timetable structure. One teacher reflected that: “... but for the purpose of teaching and learning I have not been because we go with the timetable... So we have not had the chance yet to use the computer lab”. Another teacher also experienced that: “Maybe your times come and teach for that period maybe for a month. With the computer you need to be there every day, you have to practice it every day to understand it better”. It was evident during the observation that the system of timetabling denied teachers access to the laboratory. It is also was evident from the reflection made by one of the teachers that: “I have to indicate by resources what am going to teach, use posters, maybe or real objects. Maybe I can add ICT, like in computer as the source am going to use, but it doesn’t actually appear as part of the tool that you real are going to use generally, hence I say it’s not integrate, it’s been treated in isolation!”. Even with the abundance of technological resources, teachers were not able to use them within the curriculum as a result of the structure of the school’s timetable. Sangrà et al., (2010) also reflected that the quality of learning can be improved if teachers have unlimited access to resources and services.

DISCUSSION OF RESULTS

Teachers reflected that the learning technologies policies are not implemented by the school leadership and management. This is corroborated by teachers in that though ICT/learning technologies policies in the school they are not used for teaching and learning instead Learner Teacher Support Material are used. This is inconsistent to the White paper on e-Education and Gauteng online laboratory project and Guidelines for teacher training and professional development. Similarly, teachers reflected that there is no proper plan for accessing the computer laboratory for teaching and learning. Due to a lack of a special ICT curriculum for LSEN, teachers adapted the mainstream ICT curriculum to the level of learners with special educational needs, irrespective of the challenges they faced in the teaching learners with learning disabilities.

Critical reflection enabled teacher to reflect on your own limitation of ICT skills in the teaching activities in the classroom. This reflection gives the teachers the opportunity reflect on their
own assumptions, strengths or weaknesses. Despite teachers’ lack of competence and ICT skills, learners were able to complete the activities. Furthermore, through critical reflection, teachers acknowledged that they need professional development to use learning technologies in inclusive education, workshops they attended or training do not fit or help their school. Since critical reflection enables one to reflect on one’s assumptions and beliefs, teachers reflected that they also need professional support in addressing their attitudes towards the use of ICT in their teaching practice and to eliminate fear of the unknown of using technology.

Teachers reflected that the timetable structure of the school limit them to access the use of ICT resources for teaching and learning. Teaching with learning technologies one needs to have access to the computer laboratory at least every day but unfortunately that is not the case, as there is no timetable or poster to access the computer laboratory. Using computers at the school is treated in isolation. During teachers’ teaching practice, they reflected that learning with learning technologies, learners had positive outcomes in the learning process irrespective of their learning levels or the differences in the learning areas.

CONCLUSION

The reflection as a theoretical framework of this case study is an active and careful consideration of one’s belief and knowledge in a given situational context. At the same time, the reflection can be a blending of two stages that occur in the teaching practice, that is, reflection after the event being integrated and the reflection that occurred during the event to provide a focus on ongoing improvement. Furthermore, in the teaching practice, teachers are becoming aware of their own assumptions and can revised them as a result of their critical reflection. Thus, aim of this study is to explore teachers’ reflections in the use of learning technologies in inclusive education. The research question that this study answered is: What are the teachers' reflections in the use of learning technologies in inclusive education? This is how the research question was answered - teachers reflected that (i) learning technologies policies are not implemented by the school management; (ii) they adapted the mainstream ICT curriculum to the level of learners with special educational needs; (iii) on your own limitation of ICT skills in the teaching activities in the classroom; (iv) they need professional development to use ICTs in inclusive education; (v) the need for professional support in addressing their attitudes towards learning technologies in their teaching practice; (vi) the timetable structure of the school limit them to access the use of ICT resources for teaching and learning and (vii) learning with learning technologies learners can comprehend in the learning process.

Recommendations and scope for further research are needed, since only six teachers participated in this study out of 15 teachers and it is recommended more teachers be part of enquiry. Only teachers participated in this study, a further study is needed that include learners’ reflections in the learning with learning technologies.

Both authors acknowledge that this paper is based on the Masters student work done by Sechaba Precios Pule.

REFERENCES


ABSTRACT – The motivation for this study is that people often become victims of technology abuse and cybercrime and that they are not equipped to counteract the negative effects of technology. Many studies emphasize the benefits of using technology in our daily lives. Despite people’s increased use of technology, specifically information technology (IT), there are insufficient educational efforts made regarding informing users of the dark side of technology. The dark side of technology entails all the negative side-effects of technology, such as plagiarism, information security threats, technostress, etc. In this paper, some of the main negative impacts that technology can have, are addressed. IT students’ awareness regarding the negative effects of technology is assessed in this study. It was observed that some of these issues correlate with graduate attributes that need to be developed at university level. The study employed a survey where observations in a classroom and electronic questionnaires were used. The results indicated that the students lacked adequate knowledge regarding the dark side of technology. With this information in mind, a mobile app to educate users was developed, using the data extracted from the survey and the literature study. The fact that some students are not adequately educated about the dark side of technology can imply that there is a possibility that information technology users may become victims of cybercrimes, e.g. internet scams, or at the other hand become the perpetrators by misusing the technology intentionally or unknowingly. In educating the students regarding these matters and raising their awareness, graduate attributes, such as “responsible and engaged members of society” and others are addressed.

Keywords: Dark side of technology, IT use, awareness, cybercrime, university students.

INTRODUCTION

Information Technology (IT) is a core component of current society, and it has been exponentially growing over the past few decades. IT (and technology in the broader sense) has offered users a means to improve and effectively accomplish tasks, whether for work, education, or personal benefit (Porter, 2010). However, the implementation of information technology caused negative side-effects, such as cyber-related crimes which affect people of all age groups and all walks of life. These negative side-effects are referred to as the dark side of technology which can be unintentional or intentional.

With the world becoming more accustomed to IT-related problems, it has become unclear where the responsibility lies to address or reduce the impact of these problems. According to Siegle (2017), various IT mediums offer children and learners a vast number of opportunities to learn and to express themselves; however, it is up to the parents and educators to guide them in the correct manner to utilize these mediums appropriately.

Studies over time show the immense potential of IT, but are not addressing the dark side of technology adequately. The key issue, posed by Ran (2017), is that there are insufficiently effective education methods and efforts to teach the correct and safe way to use technology. The justification of the study to explore the dark side of technology and the awareness of IT students, has as basis the phenomenon that many people become prey of cybercrime and technology abuse or at the other hand become the offenders. Raising awareness of IT students - who are the workforce of the future - regarding negative effects of technology is a way to address unwanted consequences. In this way, the new generation may be better prepared to face these challenges in a proactive way.

The research questions raised in this project were: 1) How do IT students use technology in the classroom? And 2) To what extent are IT students aware of the negative effects of technology? The paper is structured as follows: In section 2, the background to the problem is given. The research methods are presented in section 3. In section 4, the survey is discussed, while the results are presented in section 5. In the final section the paper is concluded.
BACKGROUND

The dark side of technology (focusing on information technology) has exponentially grown over the past few decades. Technology has without a doubt brought with it many potential benefits. From the innovation of the telephone, internet, mobile platforms, all the way to the creation of a rocket, technology has allowed people to achieve goals and missions which had not been possible a hundred years ago. According to the OECD (2015), in 2012, 96% of adolescents in the developed world had already access to a technological device which is an astounding increase compared to the 56.3% of the previous ten years. This also implies that the number of negative technology-related problems has also risen.

There are several types of effects on people using IT. Each type of effect may impact individuals differently, depending on who they are and what they were using the technology for. The groups may be employees, students and individuals. This paper focuses on students.

Effect of technology on students in an educational environment

Students are required to use technology extensively for academic purposes. Many universities and schools benefit from using technology in education; however, they also experience a dark side to which technology has contributed. In this section of the study, some of the issues that the dark side technology has brought to students and the educational environment are discussed.

Benefits of technology in education

Technology can be a wonderful platform for students, especially when used for academic activities. Technology brings many benefits to teaching, communicating, and learning among educators and students through e-learning and other online platforms. E-learning is the general coverage of the range of applications, learning methods, and processes used for information exchange and communication with a purpose to enable access to learning/teaching (Arkorful & Abaidoo, 2015). Educators use e-learning to share resources or as a “wholly online” tool, as used in cyberschools.

According to Nguyen et al. (2015), using technologies during class, especially the practical modules, allows students to get to see and use actual data made available by society and companies (e.g. patient data for health students). This means that students can quickly and easily obtain study-related data in vast quantities. It is also indicated that students can learn through distance-learning and therefore they are not bound by a physical location.

Negative effects of technology and the impact on students

Students are a large group of the population that interacts with technological devices on a daily basis. Students use technology to access their resources, upload their assignments, and most commonly, get help and information from the internet. Mobile phones and other handheld devices are popular mediums of technology used by students on a daily basis. This implies that technology can be used consistently and at all times. A few possible negative impacts of technology are discussed in the following sections.

a) Plagiarism

Technology platforms may enable people to share online content such as jokes, ideas or artwork and reposting are taking place very often. The boundaries of what may be reused as own work or not, may become unclear and authorship of work “is not held in high regard” by students (Taras, 2017). Therefore it is observed that plagiarism is increasingly practiced and seen as acceptable. When students use other resources, specifically the internet without the proper ethical considerations, they can be guilty of plagiarism. According to Merriam-Webster (2018), plagiarism is defined as the act of stealing someone’s ideas, words, or work and representing it as if it were that person’s original work (to commit literary theft) and usually these individuals do not indicate or acknowledge the original author. With the development of the internet, literally thousands and thousands of solutions to assignments have been made...
available and the act of plagiarizing has become much easier in comparison to previous decades. Students need to be educated to consider plagiarism as cheating, and thus, need to learn to use and reference sources correctly.

b) Smombies and technology addiction

The term smombie originated in Germany in 2015 (Chatfield, 2016) and is derived from the phrase “smartphone zombie”. It refers to the people who constantly view their smartphones while walking, resulting in strolling pedestrians who do not check the road for safety. In 2015, this term was not taken as seriously as in the following year. On 6 July 2016, the game Pokémon created a sequel game called “Pokémon GO”. The game uses players’ real locations via GPS and has players going out into their towns to catch Pokémons which are located all around their town, country, or in the world.

According to Scanlon and Neumann (2002), Pokémon GO has caused around twelve thousand accidents which have been reported to the police in Tippecanoe Country of Indiana alone. Students were often found to have missed classes to play Pokémon GO and/or were found to be casually playing it during classes.

Smombies are also caused by the constant messages and notifications on mobile devices, specifically smartphones. Addiction can set in. By having this compulsive addiction towards technology, students commonly have their smartphones on their desks during classes, tempted to use them.

c) Cyberbullying

In addition to the traditional bullying where the bullies physically hurt their victims, there is also cyberbullying. Cyberbullying is defined as a type of violence which occurs with the use of computers or cell phones (Wang, et al., 2009). Cyberbullying occurs regardless of gender and age; however, studies have shown that it is most prevalent amongst adolescents (Wang, et al., 2009). It is further stated that more boys were involved in direct bullying, whereas more girls were involved in indirect bullying. However, when it comes to cyberbullying (also known as electronic bullying or internet bullying) gender or age differences are irrelevant.

d) Isolation, unproductiveness and technology engagement

E-learning is a term that is used to describe a range of applications, learning methods, and processes used for information and resource exchange along with communication, all with the purpose of enabling access to learning/teaching which contributes to meaningful learning (Arkorful & Abaidoo, 2015). Unfortunately, the use of e-learning environments as well as other online platforms may restrict social interaction and this may lead to a sense of remoteness. The students require therefore a high-level of self-control and discipline to complete tasks (Arkorful & Abaidoo, 2015). This in turn may lead to isolation, procrastination and unproductiveness. Siegle (2017) suggests that students should sign a pledge to state that all technology use in class is solely for the purpose of class content, to respect other students while using technology, and to train them in ethical methods of using technologies in an educational environment. This young generation is the one that grew up using technology and is most likely to possess a personal device which is used on a regular basis. The implication is, therefore, that there is and increased risk of excessive human-machine interaction that may lead to the addiction to technology (Ali, 2018).

There are many other negative impacts of technology such as technostress (Salanova et al., 2013), phishing, loss of money (Morse, 2017), fake news, use of duplicate passwords (Okyle 2015), integrity of information, privacy violations, etc. (D’Arcy et al., 2014; Holland & Bardoel, 2016). Space restricts further discussion.

Solutions and recommendations

The biggest problem with the use of technology is undoubtedly the people behind it. All technology users should attempt to learn about the negative effects that technology may
cause so that they do not become victims or become the perpetrators. It is recommended that companies, organizations, and schools should implement rules or regulations and policies regarding the respectful and ethical use of technology in the workplace, academic environment, and in communication, as well as towards fellow-users (Porter, 2010). It is also suggested that IT teams should implement strong security measures to protect data physically and internally. Konradt et al. (2018) conducted a study regarding “phishing” as a method of committing cybercrime by perpetrators and the economic analysis thereof. Countermeasures should be investigated to cope with these economic losses. Awareness and education regarding cybercrime and the negative impact of technology is therefore of utmost importance.

METHODS USED

The survey conducted in this project consisted of an electronic questionnaire and observation sessions in two first-year IT student classes. Questionnaires were considered to be the most effective way to get feedback from the students – with the added benefit of collecting the data electronically and therefore no additional data entry was necessary. The sample size of the respondents for the questionnaire was 80 first-year students and the sample size of the observations was 62 first-year students. Observation was deemed to be the best way to unobtrusively determine how the students were interacting with and using the technology during class. Basic statistical tests were performed to ensure the validity of the data, along with its accuracy and reliability. The questionnaire comprised a demographics section with five questions, a technology device usage in daily-life section with five questions, a technology-use in education section with seven questions, two perception questions, three knowledge questions, three behavior questions and two previous experience of the dark side of technology questions. The questions were split into three major categories of “Perception”, “Knowledge”, and “Behavior”. There was an additional question asking the respondents about how well they think they know the negative effects of technology in order to get an indication of the students’ awareness levels. After analyzing the data, it was seen that the students lacked adequate knowledge regarding the dark side of technology. With this information in mind, a mobile app to educate users was developed, using this data extracted from the survey and the literature study. (This is not discussed further in this paper).

RESULTS AND DISCUSSION

Observation

The aim of the observation was to get insight into what the students were doing during a class session and how they used technology as part of their classroom activities. Two classes in a computer laboratory were observed. The classes consist of BSc students in IT and BCom students, both on first-year level. Table 1 presents an overview of the observation data.
62 students were observed in a computer lab. Observation was carried out in an unobtrusive way and tabulated in an Excel file, using a table consisting of columns as follows: Module name, official or unofficial participant, designated use of IT device, specific device used and other reason used.

46 students were module members while 16 other students also went into the computer lab during the class sessions. 41% of devices used for other reasons than class was smartphones. Computers were used 48% of the time for other uses. The applications the students used the devices for were mostly games/Facebook/WhatsApp – 35%. 28% of uses was for downloading movies, listening to music or watching YouTube. 13 students were not officially part of the class, but were doing other homework. The students were, therefore indeed using technology devices in the classroom either for their practical class or for other reasons as indicated, including for academic work.

**Questionnaire**

The questionnaire was developed and distributed through Google Forms to the first-year students along with the permission of and assistance from first-year lecturers. The questionnaire focused on obtaining information regarding on how well students thought they knew the dark side of technology compared to how well they actually did. Therefore, the questions were designed to be asked in types, such as questions of perception (i.e. “Do you think you can be a victim of internet scams?”), knowledge (i.e. “What is spam?”), and behavior (i.e. “I often use my smartphone during lectures for non-academic activities). Data collected from the questionnaires were exported by Google Forms to a Microsoft Excel sheet.

Once data was collected, recoded and organized, the result sets were taken to the Statistical Consultation Services. The data were analyzed with statistical software called SPSS version 25. To ensure for significance in the statistics, all relations between the relevant questions were tested to ensure that the Cronbach Alpha was near 0.5 or higher (as the sample size was relevantly small, it was suggested that 0.5 was adequate) for reliability. For the factor of “the use of mobile devices in education” the Cronbach Alpha was 0.564. In addition, it was ensured that the inter-item correlation was between 0.15 and 0.55. With the reliability test certain, it was possible to carry out the correlation test between the questions and their relations. The main groups which were tested for statistical significance were the device use (such as how often users use technology everyday) and for educational use (such as whether students used technology for academic-purposes). Each correlation between the groups ensured that the data were significant at a level of 0.01(**) or level 0.05(*), as well as for the correlation value to be between 0.2 and 0.5 (it was suggested that since the data set was collected from people and not machines, meaning that responses varied from person-to-person, a correlation value of 0.2 to 0.5 was adequate enough to accept as statistically significant).

### Table 1: Overview of observation data of first-year students in computer lab

<table>
<thead>
<tr>
<th>Reason for being in class</th>
<th># Students</th>
<th>Applications - not official use in class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Practical</td>
<td>46</td>
<td>74%</td>
</tr>
<tr>
<td>Not official</td>
<td>16</td>
<td>26%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>62</strong></td>
<td></td>
</tr>
<tr>
<td>Devices use for other uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smartphone</td>
<td>19</td>
<td>41%</td>
</tr>
<tr>
<td>Computer</td>
<td>22</td>
<td>48%</td>
</tr>
<tr>
<td>Tablet</td>
<td>1</td>
<td>2%</td>
</tr>
<tr>
<td>Laptop</td>
<td>4</td>
<td>9%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>46</strong></td>
<td><strong>46</strong></td>
</tr>
</tbody>
</table>

Data collected from the questionnaires were exported by Google Forms to a Microsoft Excel sheet.
After the reliability test, the T-test and ANOVA test were conducted. The T-test examined whether the correlation of the reliability test showed different results in respect of the different demographical groups, e.g. language and gender for two categories. If there were more than two categories, then the ANOVA test was done. The p-value (a calculated probability value) had to be below 0.05 to be statistically significant. However, since the sample size and the questionnaire itself were small, there were no significant statistical differences between the different genders or language groupings.

**DISCUSSION**

It was decided to report on simple frequencies from the questionnaire and scoring of the students concerning their perception, knowledge, and behavior on the dark side of technology issues.

The scores in Figure 1 indicate that 64% (51) of the 80 students state that they feel they know the technological dangers well. The right side of the figure presents the three categories of questions with the scores of the students for each category of questions.

![Figure 1: Frequencies from the data](image)

The students’ overall knowledge of the dark side of technology issues seems not to be too negative (69% of students answered the knowledge questions correctly). However, all these students were sitting in an IT class and one would have thought that they would have achieved a higher score. Only 25% of students could give correct answers in the behavior category, indicating that although it seems they know the dangers well and have a high individual perception of IT security awareness, this is not the case. For the perception category, only 28% of the students could achieve an overall positive awareness score for those questions. Therefore the students may need more guidance in this respect.

Table 2 presents examples of questions from each category of the questionnaire.

<table>
<thead>
<tr>
<th>Awareness category</th>
<th># Students having most questions in the category correct</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perception</td>
<td>22 - 28%</td>
<td>“On a scale of 1 to 5, how well do you think you know the negative side effects of technology use?”</td>
</tr>
<tr>
<td>Knowledge</td>
<td>51 - 69%</td>
<td>“What is a computer virus?”</td>
</tr>
<tr>
<td>Behavior</td>
<td>20 - 25%</td>
<td>“You have to do a homework report due in 30 minutes. You find another person’s assignment on Course Hero”</td>
</tr>
</tbody>
</table>
It can be observed that the students did not do so well when assessing their awareness of the dark side of technology issues. Specific questions are shown in Table 3.

### Table 3: Examples of responses to individual questions

<table>
<thead>
<tr>
<th>Question</th>
<th># students</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>I procrastinate tasks due to technology (e.g. because you want to watch a video)</td>
<td>36</td>
<td>45%</td>
</tr>
<tr>
<td>I often use my smartphone during lectures for non-academic related stuff</td>
<td>25</td>
<td>31%</td>
</tr>
<tr>
<td>I often sleep late because of technology in my room</td>
<td>45</td>
<td>56%</td>
</tr>
<tr>
<td>I often text/message someone who is physically close to me (e.g. within your house or hostel)</td>
<td>27</td>
<td>34%</td>
</tr>
<tr>
<td>Do you think you can be a victim to internet scams? (Yes…)</td>
<td>34</td>
<td>43%</td>
</tr>
</tbody>
</table>

Only certain results are given in this paper. It is seen that although it was IT students participating in this project, their use of technology and awareness of issues concerning the negative effects of technology may need attention with training programs and other awareness efforts. It would appear that students mix their academic functions and online social activities which may imply that their academic performance can be negatively impacted.

**CONCLUSIONS**

In this paper, insights gained from a project that investigated the use of technology by IT students and their awareness of the negative effects or dark side of technology were presented. The ultimate aim was to assess and raise the students’ awareness in order to prepare them for the challenges regarding cybercrime – not to become prey to cybercrime, nor to become the perpetrators thereof.

Education is vital in preventing users from becoming victim to these exploitations and in doing so prepare the students to proactively cope with these challenges in the cyber world. A follow-up study as future work could include more student groups from all year levels, thereby allowing comparisons between groups as well.

**REFERENCES**


Ran, B. (2013). The Dark Side of Technological Innovation: IAP.
ABSTRACT: Most recently, traditional universities have offered online degree courses which have been characterised by high attrition rates. In this study, students were provided with individualized online formative feedback with the aim to improve the quality of their learning. The importance of social influence (descriptive and social norms) in the acceptance and use of feedback in an undergraduate online module was investigated through a survey based on the social construct of the modified Unified Theory of Acceptance and the Use of Technology (UTAUT2). Survey data from two cohorts of students were examined using exploratory factor analysis to validate the questionnaire items and regression analysis to build a one factor predictive model. Parametric analyses showed that both descriptive and social norms were important components of social influence in the acceptance and use of formative feedback in an online course.

Keywords: Social influence, social norms, descriptive norms, UTAUT2, formative feedback

INTRODUCTION

Many traditional universities now offer online degree courses. These courses are characterized by 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). Students have also complained about lack of individualised formative feedback (Bates, 2014). Formative assessment feedback includes evidence generated from formative assessments that is used to improve the quality of learning (Black, Buoncristiani & William, 2014). 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). The Department of Science and Technology Education in the Faculty of Education at the University of Johannesburg recently transitioned one of its undergraduate modules in the Bachelor of Education (BEd) degree from traditional face-to-face learning, into a fully online module with the inclusion of individualized formative assessment feedback. Previous studies have indicated that students do not use and accept formative feedback easily (Panadero & Jonsson, 2013), and some find the lack of personalised feedback frustrating (Soden, 2017; Goto, Batchelor & Lautenbach, 2015). Not much is written about whether social influence (interactions on discussion boards, wikis, blogs etc.) affect students’ acceptance and use of formative feedback, and little is known about the importance of both components of social influence (social and descriptive norms) in the acceptance and use of formative feedback. For this reason, the question that guides this study is: How does social influence (descriptive and social norms) affect pre-service teachers’ decisions in an undergraduate online module to accept and use formative assessment feedback during authentic tasks?

THEORETICAL BACKGROUND

Social influence is only one of the factors that drives the acceptance and use of technology in many UTAUT2 studies (El-Masri & Tarhini, 2017; Huang & Kao, 2015; Venkatesh, Thong & Xu, 2012). Social influence includes both social and descriptive norms (El-Masri & Tarhini, 2017; Rivis & Sheeran, 2003). Social norms refer to what significant others think the person ought to do (Ham, Jeger & Frajman, 2015; Al-Swidi, Mohammed Rafiul Huque, Haroon Hafeez, & Noor Mohd Shariff, 2014). Descriptive norms refer to the behaviour of the significant other that motivates them to perform a certain behaviour (De Leeuw, Valois, Ajzen & Schmidt, 2015) and refers to activities of others, which may be totally different to the social norms or to what the significant other thinks.

Several authors have reported that social influence has been measured incorrectly in UTAUT2 studies (El-Masri & Tarhini, 2017; Yuan, Ma, Kanthawala & Peng, 2015). They have
been measuring, to a large extent, the social norms component, and to a lesser extent, the descriptive norms (Ham et al., 2015) thus rendering the overall influence of social influence inaccurate. Social norms have been influential in the acceptance and use of technology in collectivist (Eastern) rather than individualistic (Western) cultures (El-Masri & Tarhini, 2017, Huang & Kao, 2015; Xu, 2014; Yang, 2013; Venkatesh et al, 2012;). Social influence is also reported to have a more significant effect on women than men, in the acceptance of technology (Yu, 2012). In addition, Venkatesh et al. (2003) suggest that social influences are moderated by age and have a noticeable effect on older people particularly women. Age also influence social influence - the lower the age the more the social influence, decreasing with age (Rivis & Sheeran, 2003). One study on online games, however, reported that user experience and age did not have moderating effects on social influence (Xu, 2014). The non-significance of user experience follows from the fact that with more experience, the effect of social influences diminishes (Venkatesh et al., 2003; Venkatesh & Morris 2000). Accordingly, in this study, social influence is seen as the degree to which a student believes he or she should use formative feedback, based on the opinions of others. The moderators used in this study for social influence are age, place, frequency of accessing the online module, and time spent applying feedback per assignment.

**METHODODOLOGY**

A quantitative, non-experimental and correlational study was undertaken. 214 third year BEd students in the 2017 cohort, and 175 students in the 2018 cohort took part in the study. Students were provided with individualized online formative feedback by six experienced tutors and two lecturing staff over one semester. A questionnaire was adapted from the UTAUT2 social influence (SI) and behavioural intention (BI) constructs. To ensure construct validity, two experienced academics checked and reworded the original UTAUT2 questionnaire to fit the formative feedback context. Respondents provided answers to each item on a Likert-type agreement scale (7 point), starting from 1 (strongly disagree) to 7(strongly agree).

The first four items in cohort one on social influence included: I shared some of my formative assessment feedback with my peer(s); My peer(s) found formative assessment useful; There was a culture of sharing amongst peers regarding formative assessment feedback; My peer(s) shared some of their formative assessment feedback with me. Two more items were added for cohort two, namely: Most of my peers who are important to me are using formative assessment feedback; and, My close friends/peers are always using formative assessment feedback.

Items related to behavioural intention included: I will look out for formative assessment feedback in all future studies; I intend to use formative assessment feedback regularly in all my studies; and, I will use lessons learnt from formative assessment feedback in all my future studies.

Exploratory factor analysis (EFA) was used to validate the questionnaire items. Based on the EFA results, the convergent validity, discriminant validity and the reliability of all the multiple-item scales were analysed. The measurement properties are reported in the following sections.

**RELIABILITY: SAMPLING ADEQUACY**

The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was determined to check whether the sample size was huge enough for factor analysis to be done, hence making it possible to extract factors during factor analysis (Somashekhar, Raju & Patil, 2016). The resulting Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy for social influence was 0.781 for the 2017 cohort and 0.849 for the 2018 cohort. Both values are greater than 0.5 thus indicating that the items had good sampling adequacy. In addition, Bartlett’s Test of Sphericity was statistically significant (p<0.05) thus indicating the suitability of the collected data for factor analysis (Hair, Black, Babin, Anderson, Tatham, 2006).
Reliability was assessed using Cronbach’s Alpha, composite reliability, and inter-item total correlation which are associated with internal consistency of results. The Cronbach’s Alpha for Social influence and behavioural intention for the 2017 and 2018 cohorts were both greater than 0.7 indicating adequate construct reliability (Brown & Moore, 2012). Composite reliabilities values for both cohorts were greater or equal to 0.7 thus rendering the results acceptable (Fornell & Larcker 1981). Inter-item total correlations have factor loadings greater than 0.5 which are acceptable cut-off points (Cristobal, Flavian & Guinaliu, 2007). The composite reliability and Average Extracted Variance (AVE) for both cohorts of students exceed the 0.70 and 0.5 thresholds respectively thus indicating that the items had convergent validity (Hair et al., 2006), and thus good construct validity. Construct validity refers to the degree to which a test instrument measures the intended construct and is made up of convergent and discriminant validity.

Discriminant validity was assessed by comparing the AVE of each individual construct with corrected item-total correlation coefficients squared for each individual construct. The AVEs were larger than their corresponding corrected item-total correlation coefficients squared for social influence and behavioural intention, thus indicating adequate discriminant validity (see Hair, et al., 2006).

RESULTS AND DISCUSSION

In this section the variation of social influence with biographic information (gender, age, place, and frequency of accessing the online module and time spent applying feedback per assignment are discussed. It is important to note that the adapted social influence question items used in the 2017 cohort measured social norms only and the adapted social influence question items used in the 2018 cohort measured both descriptive norms and social norms.

THE VARIATION OF SOCIAL INFLUENCE ACROSS CATEGORIES OF GENDER.

To examine differences in social influence (social norms) for the 2017 cohort, between males and females, an independent samples t-test indicated that there was no significant difference in social influence between males and females, t (212) = 1.405, p =.161. For the 2018 cohort the descriptive statistics and an independent t-test were conducted to check the effect of gender on social influence (descriptive and social norms). The social influence mean for males was greater than for females. The independent samples t-test indicated that there is a significant difference in social influence (descriptive and social norms) between males and females, t(173)= -2.254, p =.025. Also females had lower mean social influence scores (M = 30.22; SD = 8.183) than males (M = 32.84; SD = 6.766). This finding is not consistent with prior research (Yu, 2012; Venkatesh, et al., 2003; Venkatesh & Morris, 2000; Morris & Venkatesh, 2000) where social influence was stronger in women than men.

THE VARIATION OF SOCIAL INFLUENCE WITH AGE

The distribution of social influence (social norms), across categories of age did not have any statistically significance for the 2017 cohort. This was confirmed after running the Kruskal-Wallis test, (p = 0.646; p>0.5). An analysis of variance for the 2018 cohort showed that the effect of social influence (descriptive and social norms) on age groups was significant, [F (3, 171) = 2.938, p = .035].

Post hoc comparisons using the Games-Howell test indicated that the mean social Influence (descriptive and social norms) score for the above 30 age group (M = 35.75, SD = 2.062) was significantly different from the 18 - 21 age group (M = 29.31, SD = 7.964). However, the 22 – 25 age group (M = 32.01, SD = 7.523), and the 26 - 29 age group (M = 34.54, SD = 6.802) did not significantly differ from the other age groups. The fact that social influence was greater for old students above 30 is consistent with prior research (Venkatesh, et al 2003; Venkatesh & Morris, 2000; Morris & Venkatesh, 2000). This may be indicative of older
people needing help from significant others in the early stages of technology acceptance (formative feedback in this case).

**THE VARIATION OF SOCIAL INFLUENCE, PLACE, AND FREQUENCY OF ACCESSING THE ONLINE MODULE**

A Kruskal-Wallis test conducted to evaluate differences in the distribution of social influence (social norms) across categories of place and frequency of accessing the online module for the 2017 cohort indicated that there is no statistical significance, $p = 0.333$, $p < 0.05$.

For the 2018 cohort the descriptive statics and a one-way between subjects’ ANOVA test were conducted to check the effect of categories of place and frequency of accessing the online module on social influence (descriptive and social norms).

A one-way between subjects’ ANOVA test for the 2018 cohort indicated that there was statistical significant differences for social influence (descriptive and social norms) across categories of place and frequency of accessing the online module, $[F (5, 169) = 2.301, p = .047]$.

Post hoc comparisons using the Gabriel test indicated that the mean of those students who accessed the module, 80% on-Campus and 20% off-Campus (M = 33.14, SD = 6.174) was significantly different to those who accessed the module 20% on-Campus and 80% off-Campus (M = 26.00, SD = 9.143). However, other categories of place and frequency of accessing the online module did not significantly differ between the groups. The post hoc results suggest that social interaction would take place mostly on campus where there was unlimited connectivity as compared to off-campus.

**VARIATION OF SOCIAL INFLUENCE AND TIME SPENT APPLYING FEEDBACK PER ASSIGNMENT**

A one-way between subjects’ ANOVA conducted to evaluate the distribution of social influence (social norms) on effect of time spent applying feedback per assignment for the 2017 cohort indicated that there was no significant effect of social influence on time spent applying feedback per assignment at the $p<.05$ level, $[F (5, 208) = 1.240, p = .291]$.

For the 2018 cohort, assuming for unequal homogeneity of variance of social influence (descriptive and social norms), two robust tests for equality the, Welch and the Brown-
Forsythe tests indicated statistical significance for social influence, \( p < 0.05 \) on time spent on assignment, \( F(5, 27.809) = 6.493, p < 0.00 \); \( F(5, 88.325) = 5.724, p < 0.00 \).

Post hoc comparisons using the Tukey HSD test indicated that the mean social influence score for the students who did not spend time on their feedback assignment (M = 23.20, SD = 5.541) was significantly different to those who took more than 120 minutes (M = 34.78, SD = 3.032). The mean social influence score for students who took between 1 to 31 minutes (M = 28.94, SD = 9.001) was significantly different to those students who took 91 minutes to 120 minutes (M = 35.92, SD = 4.681) and more than 120 minutes (M = 34.78, SD = 3.032). Student who spent more time on assignments had had higher social influence scores and thus engaged more socially unlike those who took less time on assignment.

**REGRESSION MODEL**

The one predictor regression was used to determine whether social influence was an antecedent for behavioural intention to use formative feedback for both the 2017 and 2018 cohort. For the 2017 cohort, the result indicates that the social influence (social norms) predictor was statistically insignificant \( (t = -0.824, p = .411, p > 0.05) \). The variation inflation factor less than 5 indicating that there was no multi-collinearity in the data.

For the 2018 cohort, the results indicated that descriptive and social norms predictors were statistically significant \( (t = -2.264, p = .025, p < 0.05) \). The variation inflation factor, less than 5, indicates that there was no multi-collinearity in the data.

For the 2018 regression model, the coefficient of social influence is negative meaning that social influence and behavioural intention are inversely related. This is consistent with prior research because according to Venkatesh, et al. (2003) social influence decreases with experience (the students obviously had some formative feedback experience in their college lives). The significance of both descriptive and social norms predictor result probably follows from the fact that South Africa is not a collectivist culture where the social norms predictor would result in a significant result but rather an individualistic culture where both social and descriptive norms are significant predictors (El-Masri & Tarhini, 2017; Huang & Kao, 2015; Xu, 2014; Yang, 2013).

**CONCLUSION**

The validation of the instrument indicated that the adapted UTAUT2 scale is accurate and reliable.

It is evident that social influence has a significant effect on behavioural intention to use formative feedback, only when both the descriptive and social norms are. This result is consistent with Ham et al., (2015). Both descriptive and social norms are precursors of behavioural intention in this case to use formative feedback. The implication of this finding is that it is important to take note of what significant others actually do and think about the acceptance and use of formative feedback. Instructional designers and course facilitators need to use social tools like blogs, discussion boards and wikis to improve the acceptance and use of formative feedback. Besides using these tools, facilitators must encourage modelling of behaviour by the students during tool use so as encourage the use of descriptive norms.

In future studies, a similar study needs to be repeated to confirm this finding. In addition, qualitative studies need to be done to determine experiences around the nature of interactions among the students engaging with the formative feedback. In addition, the use of second-generation methods of data analysis, including Structural Equation Modelling (SEM) is recommended.

**REFERENCES**


ABSTRACT—The Joint Information Systems Committee (JISC) in 2018 conducted an international pilot study on higher education students’ digital experience. The study aimed at examining students’ experiences of the higher education digital learning environment. The rationale was that, it is reasonable to understand students’ experiences with digital technology in the learning environment to reflect digital provision, digital integration into subject disciplines and to develop students’ digital skills for study and living in the 21st century. Questionnaires were distributed to students in 89 higher education institutions (HEIs) in eleven countries including Ghana. In this study, we used univariate analysis. Data from the pilot study assist in interpreting the students’ digital lives, their experiences of digital infrastructure in the institutions and digital activities in course. This paper compares results of key metrics of the questionnaire among three countries out of a set of 21 clustered studies of countries that participated in the JISC higher education insight survey. The general question addressed here is: What are the digital experiences of higher education students. We present benchmarked data of Ghana against the UK and Australia and suggest next step for infrastructure, digital integration and skills development. Based on this paper also reviews digital experiences of higher education students in the digital learning environment.

Keywords: Virtual learning environment, students’ digital experiences, digital teaching and learning, digital provision, institutional digital technology, student’s personal device and uses.

INTRODUCTION

Student’s experiences are the sum of their interaction with the institution. It includes application experiences (i.e. interactions between potential students and institutions), academic experiences, campus experience and graduate experiences (Jones, 2017; Temple, Callender, Grove & Kersh 2014). Like Temple, et al. (2014), JISC conceptualised students digital experience in the learning environment to include four components; access to and use of personal devices, experiences with institutional devices, experience of digital technology in the context of course activities as well as the students’ attitudes towards digital learning (Newman & Beetham, 2017). In this context student digital experience denote the interactions with personal and institutional digital technologies in the context of the academic program to include extra-curricular activities which students expect as part of their training in the educational setting for effective participation in the digital society.

As digital technologies and capabilities continues to alter lives at an exponential rate and becomes more and more ingrained in people’s day to day lives, it will continue to be a key asset that HEIs must make the most of to help with educational goals such as improving learning (Becker, Pasquini, & Zentner, 2017). It is also the responsibility of HEIs to prepare students for the changing job market as we enter the fourth industrial revolution. Enabling student contact with new and emerging technologies as part of learning will help equip them to adapt to the next wave of digital innovation (Fadel, Bialik & Trilling, 2015). The study therefore compares what the students’ digital experiences are in the Ghanaian context with the UK and Australia. We believe that this will provide insight to HEIs in Ghana to re-evaluate themselves and improve digital provision and experiences of students in learning that will allow the Ghanaian student to flourish in the global economy. In other words, the study will enable HEIs in Ghana to identify where they currently are, where they are doing well and where there is scope for improvement.

HE students are also inclined to make confident suggestions if they could compare their current experience with digital learning at another university. They want their experiences to be “triangulated with other sources of data (student digital experience data) about what is possible and by looking at ways that other universities support digital learning” (Newman, Beetham & Knight, 2018). The study will allow benchmarking the results with some
institutions in the UK and Australia in the JISC study and the sharing of best practices with one another. This will help guide the actions of the institutions and faculty to improve students’ digital experiences and capabilities (Gill & VanBoskirk, 2016)

The JISC-HEIS is comprehensive and versatile approach to systematically determine the students’ digital experience in context of their learning environment. JISC is a membership base organisation that allows institutions to subscribe and often provide digital solutions for HEIs and further education and research. The JISC-HEIS provide tools (for example standardised survey tool, digital advice, guidance and support) that primarily allow institutions to understand and enrich the digital experiences and skills of students in the learning environment. The digital experience insight survey allows member institutions to “collect valid, representative and actionable data from their students and to support a process for engaging students in shaping their digital experience.” (Newman, Beetham & Knight, 2018). JISC provides access to benchmark data, allowing participating institutions to compare their own results against all data of other institutions in the online system. This allows the institutions to respond to the changes in students’ digital expectations and experience of the digital learning environment; improve their experiences to enable them to flourish in the digital world; engage learners in discussions about the digital learning environment; and to gather intelligence about their changing needs. It also aimed at helping the institutions to create an optimum digital learning environment.

The JISC-HEIS also allows HEIs to articulate the digital attributes, practices, skills and understanding of higher education students. It provides a credible dataset that enable HEIs to map digital capabilities development across the curriculum, inform the development of learning and teaching support materials, and identify intended learning outcomes (Jisc, 2014). The project according to Payton (2012) dwells on how educators embed authentic academic digital task and practices meaningfully in the subject disciplines and how new tools and skills might be usefully re-contextualised in an academic setting. It also highlights the elements of digital capabilities that are essential for academic and professional situated practices, which support diverse and changing technologies and explores how HEIs, educationists, support staff to enhance students’ digital experiences on a foundation of access and functional skills (Beetham, Newman & Knight, 2018a).

Beyond the UK, several institutions including University of South Africa (UNISA) and other universities in the Australasia have been members of the JISC-HEIS project to understand how their students feel about their (the institutions) digital learning environment. In 2018, over 87 higher education institutions in the UK Australasia and Africa (Ghana) participated in the project to ascertain what their students’ views are with regard to their digital learning environment (Beetham, Newman, & Knight, 2018a; Beetham, Newman, & Knight, 2018b). The rationale was to gather evidence about the institution’s digital environment, make informed decisions, target resources for improving learning and digital capability development. This study was a part of 2018 project purposefully to gather primary data to explore the gap if any of the digital experiences of HE students in Ghana to ascertain what areas the universities in Ghana needs to support and develop.

**METHODOLOGY**

The survey instrument that was used in this research was an intact survey developed by the JISC organisation and is referred to as the ‘Higher education digital insight service’. Earlier studies suggest that students in higher education institutions own and use digital technologies to support their learning (Dahlstrom, Christopher, Grajek, & Reeves, 2015; OECD, 2015). Accordingly, this study seeks to compare seven key metrics (of the survey) on how students are using digital technologies in universities in Ghana, UK and Australia. The survey was delivered online with the BOS ‘Online system’. The survey link was distributed to the student through their email, SMS and students’ social media networks such as group WhatsApp’s and Facebook sites. The link was also published on the institutional websites. The quantitative study adopted census survey. Data was collected from students in three
leading universities in Ghana. The sample was made of 37125 final year undergraduates and postgraduate students between the ages 15 and 62 years. Some 1937 students responded to the survey representing 5.2% of the total sample. This was made up of 57% male students and 43% female student; 86% of the respondents were final year undergraduate students and 14% postgraduate students.

RESULTS

Access to digital technology carries a potential to support learning in the learning environment (Dahlstrom, Christopher, Grajek, & Reeves, 2015). We inquired about students’ ownership and use of digital tools. As might be expected the percentage difference in the devices student have at their fingertip to support learning is quite significant. See Table 1.

<table>
<thead>
<tr>
<th>Across institution: digital Ownership</th>
<th>Ghana</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Printer</td>
<td>7.3%</td>
<td>51.6%</td>
<td>61.2%</td>
</tr>
<tr>
<td>Smartphone</td>
<td>74%</td>
<td>83.6%</td>
<td>81.8%</td>
</tr>
<tr>
<td>Tablet/iPad</td>
<td>23.1%</td>
<td>34.9%</td>
<td>30.5%</td>
</tr>
<tr>
<td>Laptop Computer</td>
<td>61.9%</td>
<td>93.5%</td>
<td>94%</td>
</tr>
<tr>
<td>Desktop Computer</td>
<td>10%</td>
<td>28.0%</td>
<td>31.9%</td>
</tr>
</tbody>
</table>

The result in Table 1 shows that students’ access to digital technologies vary considerably by country with laptop and smartphones topping the list. In all 74% of students in Ghana owned smartphone, compared to 83% for students in UK and 81.8% for students in Australia. Students from Australia and UK own more laptops with nine in ten students owning laptops compared to six in ten for students in Ghana. Some 23.1% of students in Ghana owned tablets, compared to 34.9% and 30.5% for students in Australia and England respectively. Also, 7.3% of Ghanaian students owned printers compared to 51.6% for Australian students and 61.2% for UK students.

Students were asked about their experiences with the institutional resources and devices. Results shown in Table 2.

<table>
<thead>
<tr>
<th>Across institution: Digital Provision</th>
<th>Option</th>
<th>Ghana</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktop computer</td>
<td>47.6%</td>
<td>40.2%</td>
<td>40.4%</td>
<td></td>
</tr>
<tr>
<td>Laptop computer</td>
<td>13.2%</td>
<td>11.8%</td>
<td>9.8%</td>
<td></td>
</tr>
<tr>
<td>Tablet/iPad</td>
<td>13%</td>
<td>4.2%</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Smartphone</td>
<td>12.7%</td>
<td>4.8%</td>
<td>5.8%</td>
<td></td>
</tr>
<tr>
<td>Printer</td>
<td>13%</td>
<td>39%</td>
<td>41%</td>
<td></td>
</tr>
</tbody>
</table>

From Table 2, it can be seen that more students in Ghana have access to institutional desktop computers (47.64%) compared to 40.22% and 40.3% for UK and Australia students respectively. However access to institutional printers is low among Ghanaian students. Only about one in ten students in Ghana have access to institutional printers compared to about four in ten for UK and Australian students.

Helping students with their digital tools and skills will enable them to operate more effectively in the digital learning environment. The study also inquired about where students turn to first when they needed support with digital tools or skills. The result is shown in Table 3.

<table>
<thead>
<tr>
<th>Where students turn to first when they needed support with their digital devices</th>
<th>Ghana</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lecturers on my course</td>
<td>10.7%</td>
<td>8.3%</td>
<td>7.2%</td>
</tr>
<tr>
<td>Other Univ. support</td>
<td>3.4%</td>
<td>11.1%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Fellow students</td>
<td>48.2%</td>
<td>38%</td>
<td>30.7%</td>
</tr>
</tbody>
</table>
or skills | Friends and family | 15.2% | 12.7% | 13.1% |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Online information</td>
<td>22.5%</td>
<td>29.8%</td>
<td>39.6%</td>
</tr>
</tbody>
</table>

Table 3 shows that more students in Ghana (48.2%) turn to ‘fellow students’ first when they needed help with digital skills or tools compared to students in UK (38%) and Australia (30.7%). Students from Australia (39.6%) turn to seek online information first when they needed help with their digital compared to their counterparts in UK (29.8) and Ghana (22.5%). On the other hand more students in the UK (11.1%) turn to other university support compared to students in Australia (9.5%) and Ghana (3.4%), however these are in small percentages.

Comparably 49.6% of students in Australia and 42.5% of students in the UK said that their institutions help them to stay safe online compared to 22.83% of Ghanaian students.

Students were asked to rate the quality of digital provision in their institutions. Quality of digital provision in the institutions included their experiences with the institution’s hardware, software, and learning environment. Overall result shown in figure 1.

![Comparing data on students rating of their university digital provision](image)

**Figure 1:** Quality of digital provision in the institutions

On average 38.9%, students in Ghana rated their institutions digital provision above average. The students chose to rate digital provision in the institution as good, excellent and best imaginable. Some 74% of students in the UK and 90.05% of students in Australia said their institutions digital provision is above average. Less than 1.7% of students in Australia and 6% of students in Australia rated digital provision in their institutions’ as below ‘average’ choosing to rate as ‘poor’, ‘awful’ or ‘worst compared to 27% for students in Ghana.

VLE/LMSs are more useful for students in courses in the UK and Australia compared to those in Ghana. Students were asked how much they agreed with five statements about the VLE on their course. The result is shown in Table 4.

**Table 4: students’ experiences with VLEs**

<table>
<thead>
<tr>
<th>How much do you agree with the following statements about our VLE?</th>
<th>Ghana</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Across institution students’ experiences with VLEs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is well designed</td>
<td>38.40%</td>
<td>56.64%</td>
<td>60.59%</td>
</tr>
<tr>
<td>Online assessments are delivered and managed well</td>
<td>40.27%</td>
<td>58.62%</td>
<td>62.81%</td>
</tr>
<tr>
<td>I rely on it to do my coursework</td>
<td>31.13%</td>
<td>74.13%</td>
<td>86.64%</td>
</tr>
<tr>
<td>I regularly access it on a mobile device</td>
<td>39.44%</td>
<td>62.06%</td>
<td>53.45%</td>
</tr>
<tr>
<td>I enjoy using the collaborative features</td>
<td>27.25%</td>
<td>27.16%</td>
<td>34.01%</td>
</tr>
<tr>
<td>I would like it to be used more by my tutors</td>
<td>44.29%</td>
<td>43.08%</td>
<td>47.63%</td>
</tr>
</tbody>
</table>
The result in Table 4 shows that some 86.6% of students in Australia rely on VLE/LMS to do their course work compared to 74.1% for UK students and 31.1% for students in Ghana. Also, 60.6% of Australian students stated that the VLEs are well designed compared to 50% of students in the UK. Only 38% of Ghanaian student agreed to this statement. About 53.5% of Australian students agreed that they are able to access their institutions VLEs on their mobile devices, a decrease of fourteen percentage points from the 39.4% of Ghanaian students who said they do. However, more students in Ghana (44.3%) and Australia (47.6%) would want VLEs to be used more on their course compared to students in the UK (30%) who would.

Students were asked how much they agreed with five further statements about the use of digital on their course. Table 5 shows the result.

<table>
<thead>
<tr>
<th>Table 5: Support for developing digital capabilities</th>
<th>Ghana</th>
<th>UK</th>
<th>Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital skills are important in my chosen career</td>
<td>57.9%</td>
<td>69.1%</td>
<td>73.8%</td>
</tr>
<tr>
<td>The software used on my course is of industry standard and up to date</td>
<td>27.1%</td>
<td>59.6%</td>
<td>60.4%</td>
</tr>
<tr>
<td>I have regular opportunities to review and update my digital skills</td>
<td>28.8%</td>
<td>36.6%</td>
<td>40.1%</td>
</tr>
<tr>
<td>My course prepares me for the digital workplace</td>
<td>57.9%</td>
<td>69.1%</td>
<td>44.6%</td>
</tr>
</tbody>
</table>

The result shown in Table 5 shows that more students in Australia (73.8%) agreed digital skills are important in their chosen career compared to 69.1% for UK students and 57.9% for Ghanaian students. Also, more students in Australia (40.1%) agreed they have regular opportunities to review and update their digital skills in the learning environment compared to 36.6% for UK students and 28.8 for students in Ghana. Similarly, about six in ten students in Australia and UK opined that the software used on their course is of industry standard and up to date compared to Ghana (27.1%). Strangely, less than half of the students in Australia agreed that their course prepares them for the digital workplace compared to more than half for UK and Ghanaian students.

Students were asked to provide an overall rating of the quality of digital teaching and learning on their course (see Figure 2).

Overall (see figure 4.46) students in Ghana (33.9%) rated digital teaching and learning in the universities as good, 20% of the students said the universities digital teaching was poor and 2.0% it was worst imaginable. On the other hand, 41% of students in Ghana rated digital provision in their institution above average compared to 81.2% for Australian students 74%
DISCUSSION AND CONCLUSION

The study benchmarked seven key matrix of students’ digital experiences among HEIs in Ghana, UK and Australia. The purpose was to provide insight into how students use institutional digital technologies to support their learning. We identified that student experiences with digital technologies for learning are now becoming more important for all students. However, some interesting differences were identified. For example, Higher proportion of students in Australia and UK had more access to digital devices compared to Ghanaian students. This support earlier study by Galanek, Gierdowski and Brooks, (2018) which suggest that while device ownership tells us a lot about the devices students have at their fingertips, it introduces socioeconomic bias into the measure in favour of those in the developed economy in this case UK and Australia who have higher incomes than students Ghana. in addition to their own devices, more students in Ghana prefer access and use of institutional digital devices to support their learning. However, they feel that digital provision in the intuitions are not adequate and that digital teaching and learning is low on their course. Only few of the students’ rated digital provision and digital teaching and learning in the institutions above average compared to their counterparts in the UK and Australia. We also identified that students in Ghana are more likely turn to fellow students first for help with their digital tools and skills. Developing an institutional digital infrastructure, which creates a supportive, adaptable and secure digital environment, is critical for developing students’ digital experiences and capabilities. HEIs in Ghana are therefore expected to come out with strategies, policies and processes that will set the direction for student engagement with the institutional digital resources and tools and development of their capabilities.

REFERENCES


REFLECTING ON THE USE OF PROJECT-BASED LEARNING FOR 21ST CENTURY COMPETENCIES IN AN IT EXTENDED PROGRAMME

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ABSTRACT – Employment in the information technology (IT) industry will most often result in project-based environments or project-based objectives. Preparing IT students for this industry is recommended through project-based learning (PBL). PBL has become increasingly popular over the past two decades for skills development in IT-related curriculum. The use of traditional pedagogies should be critically reviewed due to the noticeable skills gap in IT graduates’ lack of 21st century competencies. This suggests that PBL should be implemented earlier in an IT degree. Literature reviews are offered on PBL and promoting reflective practice in PBL. A PBL strategy followed in an IT extended programme is presented. 30 student participants completed a reflective sheet towards the end of a module to provide insights on their 21st century competencies developed via PBL instruction. An interpretive approach is taken towards data analysis with the aim of understanding their experiences.

Keywords: Project-based learning, reflective practice, 21st century competencies, IT students, extended programme

INTRODUCTION

The goal of this paper is to highlight the value of implementing project-based learning (PBL) earlier in an information technology (IT) degree. PBL is a teaching and learning strategy where learners are exposed to real-world challenges, gaining a deeper understanding of the specific problem domain. The research questions for this study are ‘how do we understand the value of a PBL strategy taken in an IT extended degree?’ and ‘how do we improve the value of a PBL strategy in an IT extended degree?’. It is important to note that value is used as a qualitative expression of suitability or appropriateness in this paper, and not as a value to be measured.

The central objective of implementing a PBL strategy for IT extended students is to improve their 21st century competencies. It is suggested that increased learning takes place for the student, as well as the facilitator, through methods of reflection.

The paper provides literature reviews on PBL, and reflective practice in context of PBL. The PBL strategy followed in an IT extended degree module is presented. An overview of the research methodology, data collection and analysis is provided. A discussion relating to the benefits of, and suggestions for, a PBL strategy for IT extended students leads into the conclusion and overview of future research.

THEORETICAL BACKGROUND

PROJECT-BASED LEARNING

Project-based learning and other pedagogical strategies that accentuate the development of skills needed at university and when entering the work-force are becoming increasingly popular (Huberman et al., 2014; Scardamalia, 2012). The theoretical groundwork for project-based learning was introduced by Dewey’s philosophy on experiential learning and the ‘project method’ by Kilpatrick (Ravitch, 2000). The value of a PBL strategy lies in student-directed inquiry, with the aim of promoting deeper learning and supporting 21st century competencies. An overview of 21st century competencies are provided in Table 1 (Partnership for 21st Century Skills, 2019). The competencies are numbered for further use in the paper.
Table 1: Overview of 21st century competencies.

<table>
<thead>
<tr>
<th>A: Learning and innovation skills</th>
<th>B: Information, media and technology skills</th>
<th>C: Life and career skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 Creativity and innovation</td>
<td>B1 Information literacy</td>
<td>C1 Flexibility and adaptability</td>
</tr>
<tr>
<td>A2 Critical thinking and problem solving</td>
<td>B2 Media literacy</td>
<td>C2 Initiative and self-direction</td>
</tr>
<tr>
<td>A3 Communication</td>
<td>B3 ICT literacy</td>
<td>C3 Social and cross-cultural skills</td>
</tr>
<tr>
<td>A4 Collaboration</td>
<td></td>
<td>C4 Productivity and accountability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C5 Leadership and responsibility</td>
</tr>
</tbody>
</table>

With a PBL strategy, 21st century competencies are developed via student-directed inquiry instead of traditional teacher-directed approaches. Another reason PBL has been widely adopted at university level is due to poor perceived outcomes from secondary education (Duncan & Murnane, 2011). Project-based learning is seen as a strategy that can bridge these gaps by enhancing student motivation, and improving their theoretical and practical knowledge (Darling-Hammond et al., 2008; Thomas, 2000; Blumenfeld et al., 1991). Even though PBL is focused on student-centered learning, it can also be supported by facilitator-centered approaches such as lectures and demonstrations (Veletsians et al., 2016).

Artefact development is often cited as a suitable assessment for a PBL activity (Krajcik & Shin, 2014; Grant & Branch, 2005). These artefacts are typically performance-based assessments and can be used to measure difficult criteria such as 21st century competencies (Pellegrino & Hilton, 2012). A concern experienced with using PBL activities, however, is that facilitators do not have the capacity or time to provide constructive feedback, or to assist students with engaging in self-reflection (Krajcik & Shin, 2014; Grant & Branch, 2005).

PROMOTING REFLECTIVE PRACTICE IN PBL

Cohen et al. (2013, p.14) emphasise the importance of embedding reflection to improve the long-term impact of strategies taken. They indicate that students should have an opportunity to think deeply about what they have learned, and that activities that promote reflection include journaling, class discussions and responding to structured questions. Nikolou-Walker and Garnett (2004, p.307) made use of reflective journaling where students continuously answered the question ‘what did I learn?’ throughout the course of an academic year. They also incorporated structured sections to encourage reflective and learning practice. Dunlap (2006, p.21) similarly suggests providing computer science students with prompts and structured questions to assist with focusing their responses in reflective journals. Even though reflective journaling has a long history as a learning strategy in the humanities, it has only been documented over the past two decades in computer-related fields (George, 2001). Supporting PBL with reflective practice approaches can address the concern experienced where facilitators feel that they do not have the capacity to engage students in self-reflection. Even though reviewing student reflections can be labour intensive, recent efforts have been made with automated detection of reflection for analysing reflective texts (Ullmann, 2017).

When reviewing and improving curriculum content and its successfully reached outcomes, student reflection is not the only perspective to take into consideration. It is crucial that facilitators engage in reflective practice when evaluating learning approaches that were effective and ineffective. Using a PBL approach requires critical reflection to ensure that a coherent strategy is implemented, and reflected on upon completion to improve future iterations of the module.
METHODOLOGY

BACKGROUND OF INSTRUCTIONAL DESIGN

A practical module is presented in the second year of a four year IT extended degree. The content of the module centers around design processes for IT artefact creation. The theoretical component includes topics of human-computer interaction (HCI), while the practical component allows for animated artefact creation in Scratch. The curriculum development plan is built on traditional assessment methods in the form of assignments and tests, and a written examination for summative assessment. This style of teaching and learning may be considered as outdated, based on the increasing concern that South African graduates struggle to find employment. Projects are central to the IT workplace, and training future graduates in a project environment is recommended. Project-based instruction is more established in exit-level modules but adopting project-based learning earlier in a degree should be considered.

The project-based learning strategy implemented during the course of this module is presented in the next section. Factors not changed for the module include the number of study hours allocated, the assigned contact sessions during the semester and the position of the module in the degree.

PROJECT-BASED LEARNING STRATEGY

In an attempt to align module outcomes with industry expectations a decision was made to replace the written theoretical examination (summative assessment) with a project-based examination. This approach is overlooked in entry-level modules due to the manner in which Bloom’s Taxonomy is integrated at each level in the university. Creation only takes place in the highest level of Bloom’s Taxonomy, and is typically expected of exit-level students, but in an IT degree the creation of artefacts is already expected of first year students. Exposing an IT student to development and creation for the first time in his final year of study puts him at a disadvantage when entering the rapidly changing IT workforce.

For the summative assessment (examination project) of this module, students were required to create a serious game on a specific topic, along with supporting project. In order for this approach to be successful, a number of supporting formative assessments needed to be implemented. Table 2 provides a summary of all the activities that supported the project-based learning strategy, their context to the summative assessment and how they contribute toward 21st century competencies. The project is detailed in the next section.

Table 2: Overview of supporting activities in the PBL strategy.

<table>
<thead>
<tr>
<th>Activities supporting the PBL strategy</th>
<th>Context of activity</th>
<th>21st century competency addressed by activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory and practical lectures with related class exercises</td>
<td>Theory lectures pertaining to the components of HCI, interaction basics and design rules in preparation of elements to be considered in the project. Practical lectures pertaining to available gaming features in Scratch for possible inclusion in the projects.</td>
<td>A1, A2, B1, B2, B3, C1, C2, C4</td>
</tr>
<tr>
<td>Marshmallow Challenge (Wujec, 2010)</td>
<td>A Design Thinking (Brown, 2008:3) activity in preparation of Assignment 1. The aim of the activity is to encourage teams (4 members) to collaborate, think about design rules they have come across in the module, and to understand time constraints that are associated with development in the real world.</td>
<td>A1, A2, A3, A4, B1, C1, C2, C3, C4, C5</td>
</tr>
<tr>
<td>Assignment 1: Conceptual game design activity</td>
<td>A paper-based, group (4 members), class activity where teams draw a random movie theme from a hat. They need to complete a game design worksheet and indicate elements of a conceptual game based on the theme, such as the appearance of the avatar, game-play mode, the storyline, how resources are collected and used during the game, and which design rules should be</td>
<td>A1, A2, A3, A4, B1, C1, C2, C3, C4, C5</td>
</tr>
</tbody>
</table>
considered. This assessment supports the examination project in that it encourages the students to reflect on the game components they should consider in the design of their artefact.

<table>
<thead>
<tr>
<th>Short workshop on professional writing and research skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>From previous research conducted, it was explained to the students that industry members feel that students struggle with professional writing and research skills, and that Assignment 2 would contribute toward improving these skills. A short workshop was presented to demonstrate features in Microsoft Word that they may not be familiar with e.g. using Styles, proper alignment and academic language. Additionally, a demonstration of research approaches on Google Scholar, and where to find the university’s local repository was provided. Referencing was also reviewed.</td>
</tr>
<tr>
<td>B1, B2, B3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assignment 2: Research project on HCI design principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>An individual digital research report to evaluate any existing website according to design principles from theory. This assessment supports the documentation component of the exam project in that students need to write professional project documentation in which they need to indicate HCI design principles used in their exam projects.</td>
</tr>
<tr>
<td>A1, A2, A3, B1, B2, B3, C1, C2, C4, C5</td>
</tr>
</tbody>
</table>

**THE PROJECT**

One of the characteristics of PBL is that the scope of the project influences the motivation to complete the project (Helle et al., 2006). At entry-level, students cannot yet complete industry scope projects because they have not necessarily mastered the essential skills. In order to encourage the motivation of students to complete the project, they were asked to provide their preferred topics live in class using a Google Doc displayed on the overhead. The ideas were narrowed down to 7 themes. Students could vote via poll for the theme they preferred to have as scope for their exam project. The student-proposed-and-chosen theme for the 2018 exam was ‘what happens after graduation’.

The traditional written examination was replaced with a practical project. Students had to create a serious game on the topic ‘what happens after graduation’. Students completed the project in teams of two members. Game requirements included a start-up screen with relevant options, 3 levels of increasingly difficult game play, and a credit scene. Rubric criteria additionally focused on the level of coding difficulty and structure, HCI principles applied in the design, suitability of sprites and backgrounds to the theme, error handling, and presentation skills.

Project documentation included a general explanation of their game idea, the logical game play, and scoring system. Students had to report on the design process followed for their game by using the Design Thinking process model. Rubric criteria also included evaluation on formatting, referencing and professional writing.

All 21st century competencies as mentioned in Table 1 were addressed through this method of project-based learning.

The following sections focus on the research approach taken by reflecting on the methodology and data analysis that informs the results of the study.

**RESEARCH APPROACH**

An interpretive approach towards understanding the experiences and perceptions of IT extended students in context of the PBL strategy is taken. Orlikowski and Baroudi (1991) indicate that interpretive studies are preferred when a deeper understanding of data is required. Qualitative data gathering and analysis methods are used in context of interpretive research for increased understanding (Oates, 2006). Interpretive content analysis is used to prepare and process qualitative data for traceability (Zhang & Wildemuth, 2009). It is important to note that when using interpretive methods that the analysed data is not weighted. The purpose of interpretive data analysis is to ensure that all voices are heard through identified themes in the data.
RESULTS

DATA COLLECTION

The research was conducted at a university in central South Africa as part of an entry-level module in an IT extended degree. The researcher only became aware of reflective journaling towards the conclusion of the module. The approach could not realistically be applied at this point as it would lack the reflective nature that is central to the process. As a pilot study to determine if value can be derived from this approach for future iterations, students were asked to complete a structured, reflective set of questions on a single A4 page after the completion of the module. The instructions comprised of taking a moment to reflect on the activities that had formed part of the module, structured questions to indicate preferred teaching- and learning methods, and self-reflections on the skills they thought they had improved on. The reflective sheets were readily available during the first examination opportunity for the module, and students were asked to provide their reflections voluntarily and anonymously. Out of 49 students that were enrolled for the module, 34 students returned their filled-in copies. After reviewing the feedback rate, 4 copies were removed as they stopped providing reflections after the second question/ lost interest in completing the sheet. The reflections provided on these 4 sheets were reviewed for value, and the decision to discard these responses were based on the fundamental principle of the hermeneutic circle (Klein & Myers, 1999). Quantitative and qualitative data were received due to the reflective nature of writing about personal experiences. A final set of 30 completed reflective writings were included for analysis.

DATA ANALYSIS

Basic descriptive statistics were used to analyse quantitative data in the form of gender information, preferences between specific methods, and improvements in skill levels. Atlas.ti 8.4 was utilised as a scientific software tool for analysing qualitative data by identifying codes and groups. A directed approach to open coding was used to perform content analysis on the qualitative data that related to their personal experiences in context of 21st century competencies. The qualitative data analysis process followed in this paper to ensure traceability and rigour, with the aim of satisfying the fundamental principle of the hermeneutic circle, comprised of:

A directed approach to coding focusing specifically on questions and answers that were related to 21st century competencies.

Each individual question was coded based on the identified codes from the previous question. Each question made use of existing codes and produced additional codes.

When the final question was coded, the process was restarted at the first question to check whether codes that had been produced in subsequent questions were not overlooked when the process was started.

The codes for all questions were re-evaluated for coding consistency. Similar codes were merged, renamed, or deleted if redundant, which resulted in a final set of 26 unique code names across the qualitative data.

DATA REPRESENTATION

The participant gender information indicated that 63.3% female students and 36.7% male students completed the reflective sheets. Racial information was not collected.

96.7% of students indicated that they enjoyed programming in Scratch for this module. In context of the PBL strategy taken, 63.3% indicated that the marshmallow challenge was valuable, 80% benefitted from the game concept creation assignment, and 83.3% found the workshop on professional writing useful.

Qualitative findings related to the theme of 21st century competencies were included for the purpose of this paper. Structured questions (4) relating to their experiences of the formative
assessments, and suggestions for improvement were analysed. Figure 1 (depicted in the next section) provides a summary of codes identified, as well as the number of times they occurred. It is important to note that the code was counted for every occurrence across all included questions. Some answers provided such as 'yes' or 'no' did not provide value to the qualitative analysis and was coded separately under a unique code \textit{quantitative answer provides no insight} (yes/no/etc.).

\textbf{DISCUSSION OF RESULTS}

As the reflective exercise produced largely qualitative data, the discussion on results is focused on the reflections, experiences and suggestions made by the student participants. Figure 1 also depicts the codes grouped according to 5 identified themes, namely 1.) 21st century competency/skill needs further development (4 codes), 2.) Improved a 21st century competency/skill (6 codes), 3.) Benefits of following a PBL strategy (5 codes), 4.) Suggestions for improving the PBL strategy (6 codes), and 5.) Not related to outcomes of PBL strategy (4 codes). 21st century competencies improved on during the PBL strategy included time management, teamwork, critical thinking, attention to detail, problem-solving, and professional writing. The two important themes to focus on in context of this paper are the benefits and suggestions in context of using a PBL strategy.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Atlas.ti extract of all identified groups, codes and number of occurrences.}
\end{figure}

Benefits of following a PBL strategy in an IT extended programme can be summarised as:

- IT students generally enjoy the project-centered nature of a PBL approach. \textit{“It was fun.”} \textit{(participant 3)}

- IT students feel that the activities that form part of a PBL strategy promotes an environment for learning. \textit{“I learned to create ideas through animation or portray my idea.”} \textit{(participant 28)}

- IT students feel that a PBL strategy challenges them in a positive way. \textit{“It is because programming in Scratch is interesting, challenging, and mind opening”} \textit{(participant 18)}
IT students become aware of their own skill levels through a PBL approach. “It shows my way of thinking and how it can be improved.” (participant 26)

IT students focus on their future IT careers when subjected to a PBL strategy. “This will help me in the future.” (participant 4)

Student-suggested improvements for the implemented PBL strategy are summarised as:

- IT students want additional training on difficult concepts. “Perhaps give the theory part a little bit more time and lecturing I found it hard to study because some topics were new.” (participant 4)
- IT students want more homework and exercises to better prepare them. “Make the students do more assignments and challenge them more.” (participant 21)
- IT students want more context-related examples. “More examples of different coding and methods.” (participant 8)
- IT students want to be trained in as many development platforms as possible. “Combine scratch and another programme to allow students to get more knowledge.” (participant 26)
- IT students want additional support outside of the classroom. “Try to have the SI [supplementary instructor] to assist students out of class.” (participant 27)
- IT students want to keep up with current trends. “Put more time in doing external research.” (participant 29)

CONCLUSION AND FUTURE WORK

A PBL strategy was adopted in this module to improve the 21st century competencies of IT students in an extended degree. The aim of improving their 21st century competencies earlier in an IT degree is to prepare them for employment sooner. In this way, the gap between IT higher education and the IT industry can more easily be bridged.

The value of project-based learning as pedagogy for training IT students cannot be stressed enough. Even though PBL is most often used at exit-level, traditional teaching and learning methods at entry-level should also be reconsidered. This view is supported by the student participants who indicated that even though only 56.7% preferred a project-based examination to a written examination, 73.3% agreed that additional learning takes place through a project-based examination.

As part of the PBL strategy taken, a large number of the assessments were class activities and class assignments to promote increased facilitator support. A surprising finding however was that students still prefer to be overloaded with homework and specifically requested additional exercises for training (7 occurrences).

While an overall improvement in 21st century competencies of the IT extended students was clearly noticeable through the PBL strategy taken (32 occurrences total), further development of the approach needs to be refined. A strong focus of this paper is the reflection of the student as well as the facilitator. Through continuous reflection on the PBL strategy taken, it was noted that certain approaches can further be classified as guidelines for bridging the IT theory-practice gap. Some of these guidelines include:

*Interventions for bridging the IT theory-practice gap should take place earlier in a degree to raise career awareness continuously. Interventions include adapting teaching and learning approaches to the context of the industry.*

*Project-based learning is a suitable instruction method for IT education at all levels but the scope of the project needs to be managed in the context/level of the student. The motivation for entry-level students are different than that of exit-level students. Entry-level students are*
motivated by project scopes that are relevant to their current environment, while exit-level students are motivated by project scopes that are similar to what they can expect in industry. **IT students should be encouraged to engage in reflective practice on a continuous basis to highlight aspects that they need further development on.** Reflective practice can take place through methods such as journaling, reflective sheets, and autoethnography. Keeping a reflective account of the successes and struggles during the course of a module will promote self-directed learning as the student identifies competencies that he/she have mastered and need additional assistance with.

**Additional workshops on improving 21st century competencies are beneficial.** More often, educators focus only on the content of the module that they are teaching, and not on the different skills needed to support the content. For example, IT students rarely receive training on professional writing methods, as the courses are more focused on technical skills. It is however expected in industry that reports need to be written or project documentation need to be compiled. Providing a short workshop on research and professional writing may be beneficial for an IT student to complete their projects successfully, and will contribute to the quality of their assessments throughout their degree.

The research can further be extended by making use of reflective practice to review all data received via the reflective sheets for guideline building as suggested. Other available data not included in the body of knowledge for this paper comprises of self-reflections on skill levels, the created games and project documentation. The artefacts can be reviewed based on the perceptions students had of what happens after graduation when they created a theme and storyline for their games. Additional valuable data contained in the project documentation of each game is the manner in which students attempted to explain their game development in the context of the design thinking process. The data received from participants not included in this paper (as it was not directly related to 21st century competencies) could also be included for analysis to improve the future PBL strategy.

**REFERENCES**


ABSTRACT – This paper reports on the findings of a study conducted in the Umlazi District in the Kwa-Zulu Natal province in South Africa. The study involved three Physical Science teachers who were in possession of a professional qualification. The focus was on the nature of the professional development that was received by the grade ten Physical Science teachers. Due to the nature of this study being descriptive and exploratory, a qualitative case research design was adopted. To ensure trustworthiness of the data, participants responded to open ended questionnaires and were interviewed. The study aimed at answering the following research question: What is that nature of the professional development received by grade ten Physical Science teachers? The findings of the study indicated that there is no professional development workshops that focus on grade ten Physical Sciences. The findings further indicated focus areas for developmental workshops for the improvement of grade ten Physical Science teacher classroom practices, these were content knowledge, pedagogical approaches for a South African classroom and teacher practical training programmes.

Keywords: Professional development, Science, classroom practices

INTRODUCTION

Over the years learner performance in Physical Sciences in most South African schools has been reportedly poor according to various stakeholders. One critical contributory factor to this poor performance in the subject has been identified as the lack of understanding of basic concepts amongst Physical Science learners despite the fact that these concepts are introduced as early as grade ten (DBE, 2016). This study focuses on grade ten Physical Science teachers because the NSC Diagnostic reports of 2016, 2015 and 2014, revealed that the majority of Physical Science learners lacked proper knowledge on practical work as well as knowledge on scientific method and basic science concepts that are taught in grade 10. This study therefore chose to focus on the professional development of grade ten physical science teachers and the influence it has on the implementation of the grade 10 Physical Sciences curriculum in South African schools. The conceptual framework used for the study was concerned with understanding teacher’s classroom practices, within a social context (the school), from the teacher’s perspective. The ontology of the study is that teacher realities are socially constructed. The epistemology is interactive because the understanding of parts (professional development and content knowledge) leads to an interpretation of the whole (teacher’s classroom practices) and the whole leads to an interpretation of the teachers’ professional development and content knowledge.

LITERATURE REVIEW

Professional development within the context of education refers to the professional growth a teacher achieves as a result of gaining further experience and examining his/her teaching systematically (Villegas-Remers, 2003). This can be achieved through formal experiences (e.g. attending workshops and professional mentoring) and informal experiences (e.g. observations of colleagues teaching) (Villegas-Remers, 2003). “Professional development is considered an essential mechanism for deepening teachers’ content knowledge and developing their teaching practices” (Desimone, Porter, Garet, Yoon, & Birman, 2002, p. 81). For the teachers to be knowledgeable there has to be a continuous sustainable comprehensive developmental programmes in place to enhance teacher knowledge (Kriek & Grayson, 2009). Dass (1999), states that to have the developmental needs of teachers addressed adequately the single “one-shot” approach is an inappropriate and will fail. In addition studies by Fennema and Franke (1992), have suggested that the content knowledge of the teacher does influence the classroom practice. When new content is introduced in the syllabi, it creates a greater burden on the teacher (Bennie & Newstead, 1999). This is due to unfamiliarity with the content the teacher is unable to highlight certain important factors on
the new content. Thus teacher development becomes critical for successful implementation of educational change. Similarly, when there is deficit of content knowledge, then there is a need for professional development programmes to be executed (Ramnarain, 2013). The tailoring of such programmes should be around the needs of teachers. This is clearly expressed in the National Strategy for Mathematics, Science and Technology (DoE, 2001) whereby it states the need for higher education institutions to develop rigorous, high quality and relevant training programmes for teachers that will assist in strengthening both subject matter expertise and pedagogical content knowledge. However the needs of grade specific teachers must also be addressed as in this case the grade ten Physical Science teachers.

Loucks-Horsley, Hewson, Mundry, and Stiles (2009) cite several principles for effective professional development in Physical Science which they mention as, learning Physical Science content through inquiry; building understanding as a lifelong learner; and professional development opportunities that are consistent and integrate. In South Africa, professional development of teachers was often referred to as in-service education or staff development (Ono & Ferreira, 2010). Currently, some researchers have argued that the “traditional professional development workshops” (in the forms of seminars, conferences or courses and workshops) that the South African government spends millions of South African Rands on are fragmented, de-contextualized, incoherent and very isolated from the real classroom practice situations. Kelleher (2003, p. 751), refers to these traditional development workshops as “adult pull-out programmes” and is of the view that it is highly unlikely for these workshops to result in improvement of teacher classroom practice activities.

According to Supovitz and Turner (2000), professional development is still considered the best option for the reform of classroom practices of teachers due to the fact that many other alternate methods have also fared no better. For effective science professional development, researchers and teachers have come to the consensus that developmental programmes model inquiry forms of teaching(Supovitz & Turner, 2000). The advantage using programmes that model scientific reasons is that is has a greater influence on learner achievement, as compared to programmes that placed emphasis on teaching teachers to use a specific curricular (Marek & Methven, 1991).

Supovitz and Turner (2000) further state that professional development for science teachers must be intensive and engaging. It must also involve authentic tasks that are based on the experiences that teachers have with their learners. Professional development of teachers must also focus on the grade ten subject matter content and improving the teacher’s content skills respectively. Professional development of Science teachers also involves, professional development standards that show teachers how to take the knowledge gained through a workshop and connect their work to the standards of student performance for example, dealing with problem solving skills which requires teaching strategies that set higher learning goals (Supovitz and Turner, 2000). Thus when the time spent on professional development is increased, then the teachers use of inquiry based teaching practices increases and teachers establish and display higher levels of investigative classroom culture (Supovitz and Turner, 2000) This therefore informs improved classroom instruction that promote meaningful learning in a grade ten classroom.

Conceptual Framework

For this study, teacher profession development is defined as the continuous process of equipping both experienced and novice teachers with the necessary and applicable knowledge and skills required to effectively and efficiently deliver a successful grade 10 Physical Sciences curriculum in a South African classroom. The conceptual framework used for the study is based on Supovitz and Turner (2000), proposed aspects that are essential for effective professional development. Professional development directly impacts on n teacher classroom practices and teacher content knowledge. The teacher’s content knowledge and in turn also shapes the teacher's classroom practices (Desimone et al. 2002).
METHODOLOGY

Due to the nature of the study being descriptive and explanatory, a qualitative case research design was adopted, as it allowed the researcher to explore in-depth experiences of teachers in the teaching of Physical Sciences in grade 10 classrooms. The study focused on three permanently employed teachers. Selected participants had to be in possession of a recognized formal teaching qualification and give consent to the study. This study was undertaken in the Republic of South Africa (RSA) in the province of Kwa-Zulu Natal. Questionnaires and semi-structured interviews were used for data collection. Data was analyzed using the typology approach. To ensure rigor, all data collection instruments were piloted. Ethical considerations were accounted for in this study.

RESULTS & DISCUSSION

Teacher X

Teacher X has been teaching for just over 5 years. She has a Bachelor of Science degree and a Post Graduate Certificate in Education.

Researcher: How often did you attend professional development workshops? “For grade ten there is nothing”. Although Teacher X was teaching for several years she felt she still required development in the curriculum. This was evident from her response below, “Not really, some practical’s I still do not do because I don’t know how to. I don’t feel safe using the chemicals. Some sections like stoichiometry I have to read and understand first because the math is a bit difficult.” Teacher X indicated that she struggled at times with the Mathematics that was involved in Physical Sciences although she was well versed in some topics of the curriculum. When professional development focuses on subject-matter knowledge and deepen teachers’ content skills (Cohen & Hill, 1998), it then allows for teacher knowledge and skills to be enhanced (Guskey, 2009). “Having workshops that teach us a teachers how to conduct experiments, what common errors to look out for, can make my lessons so much more interesting. And if I can capture the attention of my learners I am sure issues of discipline can be eliminated, learner performance would possible improve. Such workshops will really just improve my content knowledge and skills as a teacher and I strongly feel it would even improve the way I teach.” Teacher X, felt that professional development in terms of experiments were essential i.e. Teacher Practical Training Programmes (TPTP). It would not only improve her knowledge but also her teaching as Duncal et al. (2007) explains professional development not only impacts on teacher knowledge but also results in improved classroom teaching which links itself to an increase in learner achievement. Teacher X, did not use the inquiry approach to teach. “Endothermic and exothermic reactions I use the data projector to show the burning of magnesium ribbon because I was never workshoped on doing the practical and I am not sure how to do it myself and I have to put the learner safety first.” The lack of knowledge on how to conduct experiment’s not only impacted on Teacher X’s teaching but also demotivated her at times, and this was evident in her questionnaire response, “It is embarrassing to be unable to answer questions that your learners ask you when conducting a practical, like the how, why and what happens”. “We don’t have grade ten prac workshops...my prac’s are more investigative I give the learners a set of results and ask them to interpret it”. Thus based on the responses of Teacher X, it can be deduced her practical lessons, are in fact a theory lesson because the learners are not physically engaged in doing an experiment, they are merely interpreting results. Teacher X was very keen on attending professional development workshops because she was of the belief that it would improve not only her content knowledge but also her classroom instruction. Because high quality professional development are structured in a manner that immerses the teachers in inquiry, questioning, and experimentation and therefore models inquiry forms of teaching (Supovitz & Turner, 2000).
Teacher Y

Teacher Y had been teaching for well over a decade. Her qualifications include a junior secondary education diploma, a Bachelor of Education degree with majors relating to Natural Sciences and Physical Sciences.

Teacher Y believed professional development was about the, “Development of educators to perform better in class.” In her questionnaire she explained professional development as, “Attending workshops that make us aware of better and easier approaches to teaching the topics, and make us aware of what the current field is looking at.” During interviews teacher Y alluded to professional development that would help improve her methods of approaching a topic and introducing the content to the learners, i.e. her PCK would be improved. Therefore professional development should be used as a mechanism for deepening teachers’ content knowledge and developing their teaching practices (Desimone et al., 2002). Information gained from the Diagnostic Reports and should be used as a guideline for grade 10 as grade 10 creates the foundation for grade eleven and ultimately grade twelve. The teacher’s responses and views toward professional development concurred with the works of Avalos (2011), who stated that professional development for teachers is about teachers becoming learners, learning how to learn and finally cascading this knowledge to learners in their classrooms through classroom practice. Teacher Y indicated that she did engage in professional development, however none of the programmes focused on the grade 10 Physical Science content, “Emphasis is on grade twelve work”. It is grade 10 that lays the foundation for Physical Sciences therefore it is essential that teachers teaching grade ten are proficient in their subject matter knowledge as well as methodological approaches to teaching Physical Sciences (Anthony and Walshaw 2009; Drake, Spillane, and Hufferd-Ackles, 2001; Jita and Ndilalane, 2009; Zakaria and Daud 2009). Teacher Y felt that practical workshops i.e. workshops that actually involved the teachers physically conducting experiments would in fact enhance her teaching, “Yes, yes it would really.” She then went on further to say, “I may be doing the practical and it maybe not a hundred percent correct or I could be doing it incorrectly.” “It would definitely help to have a practicals workshop that will explain the practical and how to conduct it, provide the teachers with guidelines on how to do the practicals and the CASS pieces and how to prepare learners for the exams.” When Teacher Y was questioned on the frequency of conducting experiments in class, she alluded to the availability resources as a determinant. However, the teacher’s comment “practical workshop that will explain the practical and how to conduct it” suggests that although Teacher Y was competent in terms of theoretical aspects, her ability to execute it practically was a problem. Having no professional development workshops that focused on the development of practical skills in teachers created room of uncertainty in Teacher Y. Ramnarain (2013), states that professional development programmes must be tailored according to the needs of teachers, and from Teacher Y’s response, the development of practical skills in teachers irrespective of years of experience is essential. Teacher Y envisaged professional development that equipped teachers with the knowledge and approaches to answering higher order questions; explanatory and practical workshops for prescribed experiments; workshops that developed teachers’ content and varying approaches to delivering the content. Badasie (2014), states that to achieve such outcomes collaboration is required amongst colleagues therefore professional development is conceived as a socially negotiated activity.

Teacher Z

Teacher Z had been teaching Physical Sciences for over two decades. Teacher Z indicated that there was no grade 10 Physical Sciences workshops. “the workshop focus is grade twelve, there is no workshop in term four”.

Teacher Z’s understanding of professional development was as follows, “I) being efficient in all aspects of teaching”, and II) coming to terms with the mandate that is given to you by the subject advisor, they set down guidelines to follow given by the department and the teacher
must follow it and live up to it.” Examining statement (I) above of Teacher Z, he was aware that to be a teacher in the South African classroom development was required along three dimensions simultaneously: content knowledge, teaching approaches and professional attitudes (Kriek and Grayson 2009). Teacher Z’s statement (II) indicated that he understood professional development as teachers’ acknowledging the policy documents which clearly indicated what was required to be taught, assessments to be completed and the timeline for which it was to be completed. The Curriculum and Assessment Policy Statement for Physical Sciences states that Physical Sciences is a subject that “promotes knowledge and skills in scientific inquiry and problem solving; the construction and application of scientific and technological knowledge; an understanding of the nature of science and its relationships” (DBE, 2011, p. 8). Avalos (2011), was of the view that professional development for teachers must encompasses teacher learning, learning how to learn and transforming their knowledge into practice for the benefit of the growth of their learners, and not only necessitate teacher understanding of policy documents.

In Teacher Z’s questionnaire responses he indicated that professional development also entailed,

“III) Interaction with colleagues also is part of professional development.” “IV) They are important because certain standards have been set and the teacher has to make those standards. Practice makes perfect”. Teacher Z’s understanding of professional development also included interaction with other Physical Science teachers. Such interaction would have allowed for these teacher’s to share pedagogies appropriate for teaching grade 10 Physical Sciences. Although the teacher had attended workshops, its focus was grade twelve. The pedagogies that a teacher may use to teach grade twelve mechanics would differ from that the teacher would use to teach grade 10 mechanics for the simple reason that the cognitive developmental levels of learners in the two grades differ. Teacher Z had many years of experience and excellent subject matter knowledge as a teacher; but in order for him to have been able to engage his learners in collaborative discussions to communicate scientific ideas, he required the chance to participate in professional learning thus allowing him the opportunity to learn different pedagogies appropriate for teaching Physical Sciences at the grade 10 level (Duschl and Gitomer, 1991). He would have liked professional development programmes to be structured based on the National Diagnostic Reports of examiners for the National papers that are written at the end of each academic year, “Look at the examiner’s report and look at what the problems are and deal with the identified issues. Print material for teachers to improve their content knowledge.” The teacher felt this was essential because teachers’ content knowledge and conceptual understanding of the subject has to be good in order to develop the learners’ conceptual understanding of Physical Sciences. Borko (2004), states that teachers must have rich and flexible knowledge of the subject. Teacher Z also was of the view that professional development programmes must make teachers’ aware of the common errors that learners in a South African classroom are prone to making in Physical Sciences. From Teacher Z responses the professional development that he did attend thus far was in fact not catering for his needs as a teacher, “(Researcher) Do the workshops train you in terms of practicals?” “No. The workshops do not physically do the practicals. Since 2007 there was only one occasion where practical work was actually done at a workshop.” “The disadvantage I find these days is some of the equipment for practicals is so advanced even I don’t know how to use it, yet I am an experienced teacher.” The professional development workshops that Teacher Z attended firstly did not meet his needs as a teacher. Kwok (2014) states that for professional development programmes to be effective is must address the concerns and needs of teachers. Secondly, Teacher Z indicated that he had found difficulty in the use of practical equipment, particularly new modern equipment.

CONCLUSION

In answering the research question, “What is the nature of professional development received grade 10 Physical Sciences teachers?” it is none. From the data collected all three
teachers indicated that there was no professional development that focused on grade ten Physical Sciences. The findings of the study further indicated that for the improvement of teacher classroom practices, professional development for Physical Science teachers should focus on the needs of teachers. From the interviews with the three teachers, common areas that require development were identified. These included content knowledge, pedagogical approaches for a South African classroom and teacher practical training programmes (Desimone et. al 2002; Gillies & Nichols, 2015; and Ramnarain, 2013). Thus linking the findings to the conceptual framework, professional development can be considered as a critical component for effective classroom practices. Professional development can, implicitly influence a teacher’s classroom practice through the improvement of teacher content knowledge thereby giving teachers a greater degree of confidence when teaching, and explicitly influence a teacher’s classroom practices through the development of teachers PCK and teacher practical training programmes.

REFERENCES


ABSTRACT — Employment issues in South Africa (SA) are a significant problem. Ongoing discussions in SA revolve around the employability challenges facing South African graduates, particularly in the Information Technology (IT) sector. IT graduates’ skill sets and employability status as well as the validity of the IT curriculum meeting industry needs have been questioned. A descriptive case study on graduates from an accredited, private higher education institution in SA using questionnaires and interviews was done to understand the experiences of employers, employed graduates and recruitment personnel upon employing the graduates, using qualitative analysis. This study investigated, determined and confirmed recommendations to adapt the institution’s curriculum to improve the productivity of their IT graduates upon employment, which may be of value for other higher education institutions offering IT training.

Keywords: employability; IT curriculum design; IT graduates; skills gap; skill sets

INTRODUCTION

Employment issues pose a substantial problem for the country’s economic growth (Brauns, 2013). Van Belle, Scholtz, Njenga, Serenko and Palvia (2019) found that the IT skills shortage is a higher priority in South Africa than in the developed world. Both employers and prospective employees (IT graduates) experience shortfalls and frustrations regarding the required skills that IT graduates should possess (Simon & Jackson, 2013). Pop and Barkhuizen (2010) highlight that IT graduates are not adequately prepared for the workplace. Similar frustrations have been voiced by other researchers studying the situation in South Africa (Simon & Jackson, 2013; Du Toit, Kraak, Favish & Fletcher, 2014; Taylor, 2016a). The lack of employability of the graduate labour market places strain on the economy on a global scale (Pop & Barkhuizen, 2013). Brauns (2013, p. 11) claims that, despite the rise in student numbers in tertiary education, a decline in employment is evident, adding that “employers want graduates who can do the job. It is up to colleges and students to make sure that they are ready to bridge this gap.” The study seeks to investigate and determine industry recommendations aimed at enriching the higher education curriculum within the IT sector, so that IT graduates are more productive upon employment. It indicates the impact of a lack of industry experiences upon employing new graduates, as well as the key skills such graduates lack.

The main research question explored is, “What recommendations for improvements to the IT curriculum in South Africa could be extracted from an understanding of new graduates’ first year of employment?” This led to four sub-questions:

1. What key skills do South African IT graduates lack upon employment?
2. What is the impact of graduates not being fully prepared to enter the workplace productively?
3. What measures does industry take when performance gaps are identified among employed IT graduates?
4. What would industry recommend to improve the higher education IT curriculum so that graduates are fully prepared to enter the workplace productively?

LITERATURE REVIEW

Over the past few years, South African IT graduates’ readiness for employment has been debated. Key guiding themes in such debates involve a graduate’s skill sets, employability, and the IT curriculum covered. Academics and students focus on developing technical skills, with scant attention paid to the interpersonal and additional skills graduates require when commencing employment. Employers require employees with problem-solving and critical-thinking skills, to feed the new economy. Universities are, however, not equipping students
with the necessary thinking skills: instead, they develop low-level thinking skills such as memorisation, hence they are unable to meet workplace demands (Kiener, Ahuna & Tinnesz, 2014). Graduates’ skills do not align with the needs of industry, making the subject worthy of academic attention. The following sub-sections cover key guiding themes for graduate work readiness, focusing on curriculum design, skill sets and employability.

Curriculum design

A lack of academic preparedness, large classes and inadequate curriculum design are among the challenges facing South African higher education institutions (Jaffer, Ng’ambi & Czerniewicz, 2007). Support programmes to assist in eliminating these challenges are offered, but more resources and greater expertise could be beneficial. Work-integrated learning is a vital tool for preparing new entrants for the job market (Jackson, 2013). Despite this, South African universities’ curricula are not evolving at the same fast-paced rate as the IT industry, with the result that ill-prepared students join the workforce (Moyo, 2013). Higher Education South Africa (HESA) highlights the importance of gathering information covering a graduate’s study path, all the way to employment, as this could affect changes within institutions positively (Du Toit et al., 2014). Research into whether the Information Systems (IS) curriculum meets the needs of business, has opened up an avenue for investigation into the best ways of forging stronger bonds between industry and academia, to better prepare graduates for the workplace (Howard, 2017). Howard (2017) highlights that curricula do not hone key communication skills, including skills covering team proficiencies, consolidating and negotiation skills. This means that the academic community will have to look into ways of satisfying this particular industry need by putting measures in place to change, upskill and upgrade the curriculum constantly, to align with industry needs (Travis, 2017).

Skill sets

Skill sets are crucial for securing most types of employment. An in-depth scrutiny of a graduate’s skill sets is performed prior to employment, to ascertain that the graduate would be the right fit for the position. Research has shown that there is a vital need for universities to cover more aspects related to soft skills (e.g. communication skills and professionalism) as well as for work-related experience (e.g. internships), to produce highly competent, flexible and employable individuals who are able to meet the ever-changing demands of the world of work (Andrews & Higson, 2008). This highlights the importance of hard, business-related knowledge (core competencies in the field) and the value of soft business-related skills, as well as work-related experience. Finding employment is a challenge for graduates from IT colleges and universities, mainly related to whether these graduates have attained crucial IT abilities and skill sets, including the wide-ranging general skills and profound technical skills which IT managers currently demand (Waldrop, 2017). Employers require candidates with amalgamations of behavioural skills/soft skills (e.g. communication skills such as writing skills, teamwork abilities, self-development) and technical skills/hard IT skills (e.g. designing, programming and troubleshooting skills) (Waldrop, 2017). To become more employable, graduates’ much-needed skill sets should be varied, and should include soft skills, hard skills and critical thinking skills, as well as exposure to the latest technologies (Flores, Matkin, Burbach, Courtney & Harding, 2012; Mohlala, Goldman & Goosen, 2012; Simon & Jackson, 2013; Taylor, 2016a). Thus, various skill sets play a pivotal role in developing graduates for the workplace (Amiruddin, Ngadiman, Kadir & Saidy, 2016; Taylor, 2016b).

Employability

Employability is emphasised increasingly in the higher education domain, as it is the role of such entities to produce graduates who can thrive in the 21st century workspace (Shivoro, Shalyefu & Kadhila, 2018). Ensuring that key skill sets are incorporated into the developmental stage of a student’s study life cycle will lead to better and more employable graduates entering the workspace. Reports on the CC2020 global project – which engages with the upkeep of computing curricula on a global platform, in collaboration with the Association for Computing Machinery (ACM) and the Institute of Electrical and Electronics
Engineers (IEEE) – serve to bolster graduates' employability (Impagliazzo & Pears, 2018). The CC2020 project group, which is tasked with identifying new curriculum guidelines, has found that IT competencies within curricula (for computing across all IT arenas) usually involve three key aspects: knowledge, skills and disposition. "Knowledge" refers to core concepts of the discipline of study, while "skills" covers the ability to develop and refine one’s abilities via hands-on practice and activity. "Disposition" refers to the graduate’s attitude, behaviour, social skill and emotional capabilities. Building these competencies into the curriculum will establish stronger guiding principles on how to develop graduates’ skills for the workplace.

Higher education needs to align the curriculum so that it heightens graduates’ employability through industry collaboration, to allow students to become productive members of the workforce, post-graduation. Curriculum design, skill sets and employability aspects all need to be addressed.

RESEARCH CONTEXT

The research was conducted at a South African accredited private higher education institution in the department of IT of the Applied Science faculty. The department offers two modes of study: the traditional face-to-face (lecturing), contact mode called Lecture-based Learning (LBL) and the self-directed, self-study contact learning mode called the Mastery Learning Methodology (MLM) in which most of the study material is covered via self-study whilst on campus. The modules must be completed consecutively within the specified time frame and require a 60% pass mark. The MLM mode of study offers only Higher Certificate qualifications at National Qualifications Framework (NQF) level 5. This study considered only graduates who follow the MLM mode of study.

METHODOLOGY

A descriptive case study (qualitative research) was done to determine industry’s experience with newly MLM-graduate employees to obtain guidelines for improving the curriculum. Questionnaires and interviews collected data from three IT companies employing MLM-mode graduates. Three different questionnaires were designed for the three different types of participants: line managers of employed graduates, the employed graduates themselves, and recruitment personnel. Pre-testing was conducted in the form of a pilot study.

The questionnaires focused on the role of a graduate’s results and qualification in becoming productive, and the time taken to become productive. Key skills lacked upon employment and the effect thereof on the company were explored as well as the measures put into place to counter these. In addition, recommendations for improving the curriculum were sought.

Participants were assured of anonymity to provide them with some level of comfort about sharing their experiences and feedback. The questionnaires were distributed via Google Forms, and the responses were captured automatically on a spreadsheet. Each participant's questionnaire feedback was used to create semi-structured interview questions tailored to the participant. Semi-structured face-to-face interviews were conducted with the line managers of the employed graduates and the graduates, to further probe the feedback they provided in their completed questionnaires, and to explore their experiences. Recruiting personnel shared their experiences via a questionnaire. Table 1 depicts the 12 participants' demographics.
Table 2. Participants’ demographics

<table>
<thead>
<tr>
<th>Participant</th>
<th>Duration of employment</th>
<th>Age range</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employed Graduate 1</td>
<td>2 years 4 months</td>
<td>21–24</td>
<td>Male</td>
</tr>
<tr>
<td>Employed Graduate 2</td>
<td>1 year 8 months</td>
<td>21–23</td>
<td>Male</td>
</tr>
<tr>
<td>Employed Graduate 3</td>
<td>3 years 6 months</td>
<td>22–25</td>
<td>Male</td>
</tr>
<tr>
<td>Employed Graduate 4</td>
<td>1 year 10 months</td>
<td>21–23</td>
<td>Female</td>
</tr>
<tr>
<td>Line manager – Company 1</td>
<td>12 years</td>
<td>35–40</td>
<td>Male</td>
</tr>
<tr>
<td>Line manager – Company 2</td>
<td>18 years</td>
<td>40–45</td>
<td>Male</td>
</tr>
<tr>
<td>Line manager – Company 3</td>
<td>15 years</td>
<td>40–45</td>
<td>Male</td>
</tr>
<tr>
<td>Line manager – Company 4</td>
<td>20 years</td>
<td>45–50</td>
<td>Male</td>
</tr>
<tr>
<td>Recruitment personnel 1</td>
<td>10 years</td>
<td>25–30</td>
<td>Male</td>
</tr>
<tr>
<td>Recruitment personnel 2</td>
<td>8 years</td>
<td>25–30</td>
<td>Female</td>
</tr>
<tr>
<td>Recruitment personnel 3</td>
<td>12 years</td>
<td>30–35</td>
<td>Male</td>
</tr>
<tr>
<td>Recruitment personnel 4</td>
<td>15 years</td>
<td>30–35</td>
<td>Male</td>
</tr>
</tbody>
</table>

Recorded interviews were transcribed for ease of analysis. Triangulation was used to determine whether the same or similar data sets and patterns had emerged from multiple sources (the questionnaires and interviews from all participants) by means of manual colour coding data from questionnaires and interviews.

FINDINGS

The findings from the four sub-questions are presented below and used to answer the main research question:

Sub-question 1: What key skills do South African IT graduates lack upon employment?

Soft skills in the form of communication and professional skills have been identified as among the key skills graduates lack upon employment. Feedback from participants indicated that it is difficult for employed graduates to express themselves when faced with problems and to communicate with different levels of management (“common problem has been failure to accurately verbalise… they don’t want to feel that they are silly or stupid or almost like they think they are going to give away that they don’t really belong here, if they ask something fundamental”). In addition, the ability to maintain professionalism within the work environment also appeared to be lacking (“a professional, presentable individual, that’s something unfortunately we don’t see a lot of”). The lack of professionalism includes skills such as time management (“there is no time management, we have to start from scratch”), team work (“… someone that is engaged in a team is way more productive than someone a little bit more withdrawn and not willing to join the team”), people skills, communication skills, accepting responsibility (“giving a task and then just running with it”), adaptability (“be flexible, you will always learn new things”), and conflict management (“a little bit of immaturity when it comes to conflict management”). These findings correlate with literature indicating the skill sets required for employment (Andrews et al., 2008).

A lack of practical/technical skills in IT areas of software and hardware such as debugging, working on existing systems, the proper use of version control tools, web services and servers (“all the peripheral tools from a software development environment, things like code versioning … they are not familiar with the tools, the purpose of having those tools”; “…minimum practical experience … they were not comfortable in any technical configuration”) have also been identified. These concur with the technical skills that IT managers demand, as pointed out by Waldrop (2017).

The ability to problem-solve has been pointed out as a deficiency (“taking a problem and making it your own, coming back with one, two or three possible solutions … without a lot of management intervention”; “…go look, is there something out there that can be reused?”). In addition, graduates demonstrated a lack of core subject knowledge such as multithreading in application development, web development, networking and server concepts (“what I have
done at varsity was 10% of what I actually needed to do at work … now what is a web service, they never taught me something like that at varsity”; “I'm worried that the guys do not do enough design, systems design”).

Sub-question 2: What is the impact of graduates not being fully prepared to enter the workplace productively?

Inadequately prepared graduates have a financial impact on a department without realising it (all graduates claimed that their initial lack of productivity did not impact the company). Line managers offer extra courses or identify specific certifications to upskill unprepared graduates. The employer bears the cost of the courses or certifications as well as the loss of revenue due to the graduate not being productive. Most participants believed that their higher education results did not affect the time taken to become productive. One participant offered a different view, explaining that the knowledge gained during his studies assisted him in becoming productive quickly (“the skills that I learnt in my studies, that theory and the knowledge that I gained from that is the same knowledge that I needed to do my job, it was basically applying that knowledge in the working environment”).

Sub-question 3: What measures does industry take when performance gaps are identified among employed IT graduates?

Line managers provided coaching and mentorship as well as training in specialised IT areas with Java, Microsoft and Comptia certifications. Employed graduates are also subjected to performance management on a weekly basis. Impagliazzo et al. (2018) indicate the importance of ensuring IT competencies for graduates.

Sub-question 4: What would industry recommend to improve the higher education IT curriculum so that graduates are fully prepared to enter the workplace productively?

Industry recommends paying more attention to incorporating soft skills in the curriculum as well as incorporating extensive work-related practical and technical aspects (“…include a lot of practicals, you know, real-life situations … IT certifications are now big because they prepare someone for the real-time, real-world environment in a way, you understand what you're supposed to do and you actually practise what you're supposed to be doing, as opposed to a lot of theory”). These can be achieved by collaborating with industry to expose graduates to the latest tools and concepts used in industry, and correlates with Howard's (2017) findings.

Main research question: What recommendations for improvements to the IT curriculum in South Africa could be extracted from an understanding of new graduates’ first year of employment?

The findings and recommendations were derived from the questionnaires and interviews with the participants. It was found that strengthening graduates’ skill sets by covering more soft skills, hard skills, critical-thinking skills and trending technologies would prepare the graduates better for employment. Amendments are recommended to curriculum design to include more exposure to industry-related practical work with greater exposure to industry environments by maintaining industry and academia liaisons. Greater exposure to the latest tools used in the industry would assist graduates during their first year of employment and would enhance their employability status by including IT-related certifications in specialised areas (e.g. alignment with and/or the addition of international certifications).

Both the findings and recommendations directly relate to and fed into the themes covered in the literature review, namely curriculum design, skill sets and employability. The findings further relate to the globally aligned views of the ACM and the IEEE, whose objectives are to ensure skills development and a commitment to ongoing education (IEEE, 2018). When comparing these findings to those of the ACM and IEEE’s CC2020 project, there is a direct link with the three key aspects of the CC2020 project, namely knowledge, skills and disposition. Skills relate to incorporating more hands-on practice, which ties into the finding
that more practical/technical work-related activities are needed. Knowledge relates to the need to ensure that core concepts of the discipline are covered and strengthened through exposure to the latest industry-aligned tools and concepts. Lastly, disposition entails attitudes and behaviour, which link directly to this study’s findings regarding the soft skills graduates need to hone.

RECOMMENDATIONS

Based on the feedback from the participants and the literature review, recommendations for updating the institution’s IT curriculum can be made by focusing on three areas, namely, strengthening the graduates’ skill sets, amending the curriculum design and covering employability aspects. Soft skills and hard skills can be developed by incorporating the communication and professional skills as well as industry-related practical work in the curriculum. Collaboration between academia and industry is recommended to achieve industry-related practical work. This collaboration would also lead to the graduates being exposed to trending technologies. Incorporating the development of critical thinking skills is also necessary to strengthen graduates’ problem-solving skills as required by industry. Developing the social skills associated with the attitude, behaviour and emotional abilities to allow graduates to be successful in the workplace, as recommended by the CC2020 project, will enhance employability.

Amending the curriculum design to incorporate the key skills required can be aided by academia-industry collaboration to afford greater exposure to industry-linked environments that would ensure hands-on activities and practices, which is also recommended by the global CC2020 project. Finally, employability recommendations also indicate the need to include IT-related certifications in specialised areas that align to international certifications, incorporating core discipline-related concepts.

CONCLUSION

This case study investigated the experiences of newly graduated IT employees and their managers to obtain industry’s recommendations to improve the undergraduate IT curriculum of a private higher education institution in South Africa, with the aim of better preparing graduates for their first year of employment. The findings show the financial impact unprepared graduates have on industry, and that with better preparation, new graduates could be more productive within their first year of employment. Vital skills that the graduates lacked entail various components of both soft and industry-related practical skills. As discussed in the recommendations, enhancing the IT curriculum would equip new graduates with industry-required attributes that would assist in providing better prepared graduates for industry.

The data collected reflected noteworthy trends, confirmed by the literature, that offer valuable preliminary points for more informative studies on the topic of curriculum enhancements in higher education in relation to the IT sector.

REFERENCES

ABSTRACT
New and emerging technologies continue to disrupt the teaching and learning processes and these new innovations are not always easily accepted. In this study, the researchers employed Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) in order to identify the factors that influencing the use and acceptance of a digital emerging technology called the VIA App at a private higher education institution in South Africa. VIA App is a wireless presentation and synchronous collaboration application affording multiple users access to shared content that can be review a quantitative descriptive approach and amended in real-time during the learning process. This qualitative study made use of a questionnaire to test six of the UTAUT2 constructs to determine acceptance using a 5-point Likert scale. Results indicate constructs such as performance expectancy significantly influence the use and acceptance of VIA app. In addition, findings suggest that effort expectancy, social influence, facilitating conditions, hedonic motivation and habit partially influence the use of the VIA App during teaching and learning. Pre-service teachers’ gender was also found to be significant determinant to the overall acceptance and use of the synchronous and collaborative VIA App.

Keywords: Acceptance and use of technology, Unified Theory of Acceptance and Use of Technology 2, UTAUT2 model, pre-service teachers, VIA App, Synchronous and collaborative learning in online spaces

INTRODUCTION
Information and Communication Technology (ICT) integration is pervasive in tertiary institutions as far as the teaching and learning process is concerned. As a result, new ICT solutions are introduced to teaching and learning spaces such as in schools and universities resulting in new pedagogical practices that are met with varying degrees of success (Ng’ambi, Brown, Bozalek, Gachago & Wood, 2016). New online applications are becoming popular in the mediation of learning resulting in various ways of engagement with content in the 21st century classrooms. An application can be seen as a software computer program or to any desktop or mobile application (Wong, 2012). To make use of such new applications, educators such as lecturers and teachers should be well equipped in terms of digital pedagogical skills to enhance their confidence in the use of technology tools in their learning spaces (Comi, Argentin, Gui, Origo & Pagani, 2017; Englund, Olofsson & Price, 2017; Nikolopoulou & Gialamas, 2016). Woodcock, Sisco, and Eady (2015) found that synchronous e-learners seem to engage in consistent communication, have greater focus on activities, and display patterns of increased participation. Discussions in concept clarification during lectures was also found to be beneficial in synchronous learning spaces such as in chat rooms, quizzes, or just as oral communication (Chen, Wei & Huang, 2013).

Berson, Berson and McGlinn-Manfra (2012) posit that the integration of different apps which are well-sequenced enables learners to improve their digital literacy skills through their collaborative and personalised experiences. Exposing pre-service teachers to new technologies, including synchronous online computer supported collaborative learning tools, can impact their ways of communication, and influence their approach to teaching and learning in the 21st century and better prepare them as future educators (Okeke, Van Wyk & Phasha 2014). Some of these applications are now specifically being developed to facilitate real-time content presentation and engagement, such as the VIA App used in this study.

VIA is a wireless presentation and collaboration application used in the majority of lecture rooms at a Private Higher Institution. For pre-service teachers to be able to use this application, they have to install it on their smart devices. The VIA App has a multimedia feature which is sharable through High-Definition (HD) wireless video streaming platform and
can house 254 devices through the wireless connection. It has a function of sharing and reviewing of content function and can accommodate real-time messaging. For participants to enjoy the VIA app, they have to login-in using the room number and the code provided normally generated once an attempt of logging in is initiated. The main display of the VIA app can be viewed by the presenter, students or anyone present in the room. Pre-service student teachers find it difficult to see the relevance of employing technologies during the teaching and learning process in their academic discourse having had not much prior exposure before enrolling in the programme. As such, the extent to which they accept and use of these technologies impact on their actual use in future scenarios (Rikhotso, 2016). Therefore, the purpose of this study was to interrogate first year pre-service teachers’ acceptance and use of the VIA App at a teacher training institution through the use of Venkatesh, Thong and Xu’s (2012) UTAUT2 model.

LITERATURE PERSPECTIVES

The UTAUT model was developed by Venkatesh, Morris, Davis and Davis, (2003) to keep abreast with technology acceptance and was informed by the Technology Acceptance Model (TAM) of Davis (1989). Furthermore, Unified Theory of Acceptance and Use of Technology was further revised in 2012 by Venkatesh and colleagues resulting in the UTAUT2 (Ravangard, Kazemi, Abbasali, Sharifian & Monem 2017). Fathema, Shannon and Ross (2015) observed that the UTAUT2 model was strongly influenced by Fishbein and Ajzen's Theory of Reasoned Action (TRA) and is a natural extension of the Technology Acceptance Model (TAM). Much has been written about the usefulness and ease use of technologies including ICTs as part of determinant factors of acceptance (Cassim & Obono 2011; Nair & Das 2012). More can to be learnt about additional factors that may contribute to greater acceptance of new technologies in teaching and learning spaces.

Performance expectancy (PE) emphasises usefulness as indicated by TAM model (Miltgen, Popovič & Oliveira, 2013) and reflects the advantages normally perceived by individuals after using technology in doing certain activities (Venkatesh, et al., 2003). A variety of studies have also confirmed the significance of performance expectancy a construct (Chang, Ng, Sim, Yap & Yin, 2015; Raman & Don, 2013; Venkatesh, et al., 2012; Wang, et al., 2009). Performance expectancy has also been viewed as a predictor, in UTAUT2 and UTAUT models in the health and financial sectors and proved to be good to patients who perceived e-health as useful to the extent that they adopt it and in banking clients increasingly migrating to online banking options (Lemire, Pare, Sicotte & Harvey, 2008; Martins, Oliveira, & Popovič, 2014; Wilson & Lankton, 2004). UTAUT2 as a model of acceptance and use is employed in multiple disciplines and various industry sectors such: commerce, marketing and business lending more credibility in research.

Effort expectancy (EE) focuses on ease of use perceived as advocated by the TAM model (Miltgen, et al., 2013) also associated with how easy it seems to be to use a certain technology (Venkatesh, Morris, Davis & Davis, 2003). Effort expectancy as a construct verifies whether the students find it easy to use the VIA app, if so, to what extent can they can adopt it in their pedagogy during teaching or as qualified teachers. However, Hackbarth, Grover, and Yi (2003) found that as experience is gained through continuous use of a given technology, it is perceived that effort expectancy construct becomes less important.

Social influence (SI) is the influence by the significant other which will result in an individual making the decision to use technology or participate in a technological activity (Venkatesh, et al., 2003). Social influence also positively influence mobile learning adoption as reflected by lecturers and pre-service teacher survey that was conducted in at a university in Iraq (Jawad & Hassan, 2015). In this research, the social influence construct will measure the extent to which the pre-service teachers are influenced by their peers to use the synchronous collaborative VIA App. Sharples, Taylor and Vavoula (2010) caution that modern students are more likely to make independent decisions without being influenced by people surrounding them such as family members, friends or lecturers.
Facilitating conditions (FC) is another construct that is concerned with the perception of an individual aligned to the support available in order to perform a technological activity (Venkatesh, et al., 2003). Thomas, Singh and Gaffar (2013), based on the survey conducted at the University of Guyana, posit a behavioural intention that is positively related to facilitating conditions in m-adoption of mobile learning. Hedonic motivation (HM) is having fun or pleasure from a technology activity by an individual and is viewed as part of intrinsic motivation (Venkatesh, et al., 2012). It has been found that behavioural intention and hedonic motivation are related in the use of mobile learning solutions as captured in a study of 3rd year students at a University in South Africa (Bere, 2014). In this study, the hedonic motivation construct is viewed as a source of entertainment, satisfaction and enjoyment to the extent that an individual student gets pleasure from using the VIA App. Lastly, habit (H) as a construct in UTAUT2, as a result of learning automatically triggers a certain behaviour that seems to become natural to the user (Ahmed, 2016). If we hold the view that behavioural habits exist in individuals, then also manifest in learning cycles where individuals repeat activities of how an application is used. This study aims to utilise the UTAUT2 in order to identify the factors that influence the use and acceptance of the VIA App in pre-service teachers at a private teacher training institution.

RESEARCH METHODOLOGY

This study employed a quantitative research approach making use of convenience sampling and relied on data collected from pre-service teachers who were expediently available to participate in study. Prior to sampling, respondents were exposed to the VIA App for intermittently for 10 calendar months. A survey technique through the use of an online questionnaire was deployed across the three different campuses of the particular private teacher training institution respectively Durban (X), Midrand (Y) and Pretoria (Z). According to Mathers, Fox, and Hunn, (2007), questionnaires is considered as a convenient way of collecting data from a large group. The instrument comprised of two sections. The first section covered questions related to the demographic profile. The second section comprised of 23 questions using a 5-point Likert-scale statements attesting to the level of agreement that aligned to six constructs adapted from UTAUT2 (Venkatesh, et al., 2012). Gender, academic program, age and campus encompass the demographic profile. The questionnaire was administered using the Microsoft (MS) forms platform with a link sent via email to all first year pre-service teachers after permission was granted to conduct the research at the particular institution. Data was collected over a period of twenty-five days. After the online questionnaire’s due date, the collected information was downloaded and saved in an Excel spreadsheet through the MS forms platform tool in preparation for importing into the SPSS software package for statistical analysis.

RESULTS AND DISCUSSION

The reliability and validity of results measured by computing for Cronbach’s Alpha should be 0.7 or above in terms of values (Mutlu, 2016). The Cronbach's Alpha of PE, EE, SI, FC, HE and H based on the constructs utilized in this study for the 23 items is 0.945. This is greater than 0.70. As such, this reflects internal consistence of reliability of the variables in relation to VIA App acceptance.

Table 1 below displays gender as an element of the demographic profile and Table 2 presents the age distribution of respondents across four various age groups.
From Table 1 and 2, it is evident that the greater majority of respondents are female (81.4%) and fall in the age bracket of between 19 – 24 years of age (65%).

Jacobs and Jacobs (2014), suggested that Mann-Whitney U test as a non-parametric technique in statistics as suitable when employed to analyse responses of two groups in line with the median differences. Kan (2016) and Jacobs and Jacobs (2014) further propounded that values measured on an ordinal scale can be compared, as they do not follow a t-distribution or the normal distribution. Kan (2016) further emphasised that the use of the Mann-Whitney U- test is to determine significant pairwise. The data in this study is not normally distributed, hence, the use of Mann-Whitney U test was appropriate. Table 3 below shows the test statistics of gender in relationship with items based on performance expectancy of pre-service teachers who participated in this research and displays the data generated using Mann-Whitney U test in order to test for significant differences between gender and the variables which describes usefulness, efficiency, time consuming as well as VIA’s helpfulness.

Table 3 - Test statistics in relation to performance expectancy of pre-service teachers

<table>
<thead>
<tr>
<th>Test Statisticsa</th>
<th>8.1 VIA is useful in daily life</th>
<th>8.2 VIA is a time-consuming tool</th>
<th>8.3 VIA can do things more quickly</th>
<th>8.4 VIA helps me to learn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mann-Whitney U</td>
<td>1655.000</td>
<td>1894.000</td>
<td>1763.000</td>
<td>1564.000</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>10040.000</td>
<td>10150.000</td>
<td>10019.000</td>
<td>9820.000</td>
</tr>
<tr>
<td>Z</td>
<td>-1.564</td>
<td>-1.409</td>
<td>-1.443</td>
<td>-1.391</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.118</td>
<td>.683</td>
<td>.658</td>
<td>.164</td>
</tr>
</tbody>
</table>

a. Grouping Variable: 1. Gender

In previous studies, hedonic motivation was perceived as a non-significant predictor in a College of Engineering but was only highly significant for a College of Education, (Ahmed 2016). In this case as depicted in Table 4, hedonic motivation was analysed in relation to age. The varied age groups perceived the VIA App as not enjoyable even though it entertained them. It might mean because they have been exposed to it for a prolonged period of time, they no longer feel motivated by it.

Table 4 - Test statistics in relation to hedonic motivation

<table>
<thead>
<tr>
<th>Test Statisticsab</th>
<th>12.1 I do not enjoy using VIA</th>
<th>12.1 Reverse coded</th>
<th>12.2 Using VIA is entertaining</th>
<th>12.3 I see little value in using VIA</th>
<th>12.3 Reverse coded</th>
</tr>
</thead>
<tbody>
<tr>
<td>df</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.027</td>
<td>.027</td>
<td>.192</td>
<td>.177</td>
<td>.177</td>
</tr>
</tbody>
</table>

a. Kruskal Wallis Test
b. Grouping Variable: 2. Age group
The findings indicate that the respondents perceived *effort expectancy* as relatively of equal importance across the variable as displayed in Table 5.

**Table 5 showing confidence interval in relation to effort expectancy**

<table>
<thead>
<tr>
<th>Descriptives</th>
<th>Statistic</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>9.1 Learning to use VIA is easy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female Mean</td>
<td>2.57</td>
<td>.100</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.37</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>2.76</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.52</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Male Mean</td>
<td>2.83</td>
<td>.228</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.36</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>3.29</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.81</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td><strong>9.2 Interaction with VIA is clear</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female Mean</td>
<td>2.40</td>
<td>.094</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.21</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>2.59</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.36</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Male Mean</td>
<td>2.86</td>
<td>.220</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.41</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>3.11</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.85</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td><strong>9.3 VIA is easy to use</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female Mean</td>
<td>2.44</td>
<td>.096</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.25</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>2.63</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Male Mean</td>
<td>2.83</td>
<td>.211</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.40</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>3.26</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.81</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td><strong>9.4 I am skillful at using VIA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female Mean</td>
<td>2.17</td>
<td>.091</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>1.99</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>2.35</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.12</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>Male Mean</td>
<td>2.52</td>
<td>.208</td>
</tr>
<tr>
<td>95% Confidence Interval for Mean</td>
<td>Lower Bound</td>
<td>2.09</td>
</tr>
<tr>
<td>Mean</td>
<td>Upper Bound</td>
<td>2.94</td>
</tr>
<tr>
<td>5% Trimmed Mean</td>
<td>2.46</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>3.00</td>
<td></td>
</tr>
</tbody>
</table>

On this basis, it can be said that males value and believe that they are skilful as far as the use of the VIA App is concerned and partially satisfies the influence of *effort expectancy*. After calculating the median for the *Learning how to use VIA* variable, the researcher found 25-30 years Median (Mdn) = 1.50, however, the rest of the age groups displayed a Median = 3. Therefore, the respondents both males and females believes that the use of VIA is easy.

Pre-service teachers *effort expectancy* within various age group, indicate that the Kruskal-Wallis H test value ranges from 4.282 to 8.324 as displayed in Table 6. The degrees of freedom (d.f) is 3 across the age groups which participated.
Table 6 - Test statistics of age group in relation to Effort Expectancy of pre-service teachers

<table>
<thead>
<tr>
<th>Test Statistics&lt;sup&gt;a,b&lt;/sup&gt;</th>
<th>9.1 Learning to use VIA is easy</th>
<th>9.2 Interaction with VIA is clear</th>
<th>9.3 VIA is easy to use</th>
<th>9.4 I am skilful at using VIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kruskal-Wallis H</td>
<td>8.324</td>
<td>4.282</td>
<td>6.466</td>
<td>5.050</td>
</tr>
<tr>
<td>df</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.040</td>
<td>.233</td>
<td>.091</td>
<td>.168</td>
</tr>
</tbody>
</table>

<sup>a</sup> Kruskal Wallis Test  
<sup>b</sup> Grouping Variable: 2. Age Group.

Findings indicate that the respondents perceive facilitating conditions as equally important across the variable with an exception of females who had less in median value as displayed in Table 7. Male respondents perceive facilitating conditions as more important in comparison to female respondents. The maximum difference observed in variable 11.2 (I have necessary knowledge to use VIA) is 22.6% (96.75% - 74.15%) and in 11.4 (I ask for help from others when I have difficulties using VIA) is 21.18% (96.13% - 74.95%). As such, males seem to be influenced by having VIA as a resource and they are prepared to ask for help whenever necessary.

Table 7 - Gender mean ranks in relation to facilitating conditions

<table>
<thead>
<tr>
<th>Ranks</th>
<th>1. Gender</th>
<th>N</th>
<th>Mean Rank</th>
<th>Sum of Ranks</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.1</td>
<td>I have the resources to use VIA</td>
<td>Female</td>
<td>130</td>
<td>78.45</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>31</td>
<td>91.69</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>161</td>
<td></td>
</tr>
<tr>
<td>11.2</td>
<td>I have the knowledge to use VIA</td>
<td>Female</td>
<td>126</td>
<td>74.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>30</td>
<td>96.75</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>11.3</td>
<td>VIA is compatible with other technologies I use</td>
<td>Female</td>
<td>126</td>
<td>76.89</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>30</td>
<td>85.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>11.4</td>
<td>I ask for help when I have difficulties using VIA</td>
<td>Female</td>
<td>127</td>
<td>74.95</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Male</td>
<td>30</td>
<td>96.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total</td>
<td>157</td>
<td></td>
</tr>
</tbody>
</table>

The confidence interval of Habit in relation to gender as reflected in Table 8, indicates that female pre-service teachers' median as Mdn = 2. They regarded the use of VIA as a habit with a significant confidence level of 95%. It is interesting that the male median was Mdn=3. The male respondents perceived the use of VIA to be more important than their females counterparts. On the variable I can get addicted to using VIA, it indicates an equal median of 3 for both males and females and confidence level 95%.
Table 8 - Habit and gender confidence intervals

<table>
<thead>
<tr>
<th>Descriptives</th>
<th>13.2 I can get addicted to using VIA</th>
<th>13.2 I can get addicted to using VIA</th>
<th>13.3 I must use VIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>Mean 2.05 (.094)</td>
<td>Lower Bound 1.86</td>
<td>Upper Bound 2.23</td>
</tr>
<tr>
<td></td>
<td>95% Confidence Interval for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5% Trimmed Mean 1.99</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median 2.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>Mean 2.13 (.196)</td>
<td>Lower Bound 1.73</td>
<td>Upper Bound 2.53</td>
</tr>
<tr>
<td></td>
<td>95% Confidence Interval for Mean</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5% Trimmed Mean 2.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median 2.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9 Kruskal-Wallis Test — Campus in Relation to Habit of Pre-service teachers

<table>
<thead>
<tr>
<th>Test Statistics</th>
<th>13.1 Using VIA is a habit</th>
<th>13.2 I can get addicted to using VIA</th>
<th>13.3 I must use VIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kruskal-Wallis H</td>
<td>4.694</td>
<td>5.044</td>
<td>1.428</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Asymp. Sig.</td>
<td>.096</td>
<td>.080</td>
<td>.490</td>
</tr>
<tr>
<td>a. Kruskal Wallis Test</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Grouping Variable: 4. Campus</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After calculation of median based on the data in Table 9, the median on using VIA as a habit was 2 across all campuses, with a confidence level of 95% indicating respondents to perceive VIA to be habit forming in their usage of it. In Table 10, variable 13.1 (I can get addicted because of using VIA), it is clear that the median for Y is one while X and Z shared two.

Table 10 mean ranks of Habit in relation to campus.

<table>
<thead>
<tr>
<th>Ranks</th>
<th>4. Campus</th>
<th>N</th>
<th>Mean Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.1 Using VIA is a habit</td>
<td>X</td>
<td>92</td>
<td>83.27</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>51</td>
<td>69.22</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>15</td>
<td>91.33</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>158</td>
<td></td>
</tr>
<tr>
<td>13.2 I can get addicted to using VIA</td>
<td>X</td>
<td>93</td>
<td>83.72</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>50</td>
<td>67.26</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>13</td>
<td>84.38</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>156</td>
<td></td>
</tr>
<tr>
<td>13.3 I must use VIA</td>
<td>X</td>
<td>93</td>
<td>80.75</td>
</tr>
<tr>
<td></td>
<td>Y</td>
<td>50</td>
<td>72.01</td>
</tr>
<tr>
<td></td>
<td>Z</td>
<td>12</td>
<td>81.63</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>155</td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

This study revealed that the performance expectancy significantly influence the adoption, use and acceptance of VIA app. On the other hand, effort expectancy, facilitating conditions, and habit partially satisfies the influence towards the use of VIA amongst the respondents in this study through gender. It is interesting to note that, gender and age also contributes to the acceptance and use of the Via App. Furthermore, a synchronous online collaborative application such as the VIA App also contributes to the development of the 21st Century skills as the pre-service teachers prepare for teaching and learning in the future. Despite its limitations, this study provides useful insight into the factors that influence the use and
acceptance towards new synchronous collaborative technology tools in teaching and learning environments and recommend that careful consideration should be given to gender and age in the implementation of new and emerging technologies in teaching and learning spaces. These findings will benefit lecturers, teachers and policy makers who seek to ensure the successful implementation and adoption of an application with similar affordances in the actual teaching and learning field.

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ABSTRACT: The leitmotiv of this paper is the relationship between the natural sciences and indigenous knowledge, and whether indigenous knowledge has a place in the school science curriculum. In this review paper, various perspectives on the role of indigenous knowledge in the science classroom are explored. Based on the tenets of respective science and indigenous knowledge, three different perspectives on such epistemological border-crossing are explored: the inclusive, the exclusive, and the ‘overlapping domains’ perspectives. The authors also consider factors that influence such border-crossing, such as teacher and learner factors.

Keywords: Indigenous knowledge, science education, border-crossing, tenets of science, tenets of indigenous knowledge

BACKGROUND

During the #FeesMustFall campaign that disrupted higher education since 2015, the focus was on the decolonisation of the curriculum (De Beer, 2016). During the colonialised era, indigenous knowledge was not considered important and much of the knowledge was lost (Diwu & Ogunniyi, 2012). In the new democratic South Africa, this concern has been addressed, with indigenous knowledge being accommodated in the school science curriculum. In the Curriculum and Assessment Policy Statements (CAPS), Specific Aim 3 focuses specifically on the integration of indigenous knowledge in the science classroom (Diwu & Ogunniyi, 2012; DOE, 2011). This Specific Aim is concerned with learners’ understanding and appreciation of the connection between the scientific content (curriculum) and their everyday lives, and how this scientific knowledge can enrich their lives (DOE, 2011). Indigenous knowledge holds affordances to better contextualise science for learners. However, Zinyeka, Onwu, and Braun (2016) also indicate that a particular learner might decide to not choose science as a subject, because of the perceived clash between his/her cultural principles and the scientific aspects. The epistemological border-crossing between science and indigenous knowledge in the classroom is, therefore, of utmost importance.

DEFINITION OF INDIGENOUS KNOWLEDGE

Indigenous knowledge is defined as knowledge that is transmitted from one generation to another, through storytelling, drawings, and dancing (Nyang, Adesina & Elasha, 2007). This knowledge is unique to a specific group of people or culture living in a specialised socio-cultural environment (Shizha, 2013). Anazifa and Hadi (2017) emphasize the importance of the interaction between indigenous people and the environment in which they live in. This knowledge has evolved over centuries and is especially focused on sustainable agriculture, food preparation, health and environmental conservation (Anazifa & Hadi, 2017). Unfortunately, not much of this knowledge has been documented (Anazifa & Hadi, 2017) and some knowledge has been lost for next generations (Fraser, 2012). According to Anazifa and Hadi (2017), this loss of indigenous knowledge could be accredited to a communication gap between the elders and the youth of the community. The youth of the community often moves away from the rural areas and consequently also loses contact with their culture (Anazifa & Hadi, 2017). Anazifa and Hadi (2017) explain that indigenous knowledge has a great influence on our “modern” life, like medicine, architecture, engineering, agriculture and pest control (Diwu & Ogunniyi, 2012). For this reason, the infusion of indigenous knowledge in the school science curriculum is of paramount importance.
DEFINITION OF NATURAL SCIENCE (WESTERN KNOWLEDGE)

Shizha (2010) explains that Western science focuses on repeatable observation descriptions, predictions and experiments related to the physical world. Scientific knowledge refers to abstract concepts such as theories and laws, and the scientific methods (Le Grange, 2016). According to Lederman, Lederman and Antink (2013), scientific knowledge is based on experiments, observations, theories, and laws. De Beer and Mentz (2016) add that the formulation of hypotheses, selecting the appropriate method of investigation and testing the hypotheses play important roles in the collection of scientific knowledge. There are strict protocols that exist when hypotheses and experiments are done to ensure that information is reliable (De Beer & Mentz, 2016).

THREE DIFFERENT VIEWPOINTS ON THE INTEGRATION OF INDIGENOUS KNOWLEDGE INTO THE SCHOOL SCIENCE CURRICULUM

According to Zinyeka et al., (2016:257) and Taylor and Cameron (2016), there are three different perspectives on the integration of indigenous knowledge in the natural science school curriculum:

1. **The inclusive perspective** – this perspective considers indigenous knowledge as part of science.
2. **The exclusive perspective** – sees indigenous knowledge and science as separated knowledge domains. The many foci of the science domain are in the material world. The indigenous knowledge domain is in contrast with the science domain because this domain also recognises the possibility of supernatural elements.
3. **Overlapping perspective** – with this perspective there is an overlap between the indigenous knowledge domain and the science domain. This perspective highlights that there are some aspects or elements of both domains that are similar, yet each of the domains also has unique elements.

In this paper, we shall critically discuss each of these perspectives.

1. **Inclusive perspective**

The inclusive perspective views indigenous knowledge as part of science. Figure 1 shows that certain tenets are shared by both these knowledge domains, which ease this epistemological border-crossing in the science classroom.
Taylor and Cameron (2016) explain that, according to the inclusive perspective, indigenous knowledge is taught as part of the science curriculum and is regarded as a science. Unfortunately, the uniqueness of each knowledge domain can be lost with such an approach. Especially, the identity of indigenous knowledge gets lost because what makes indigenous knowledge special (e.g. its holistic nature) gets overshadowed by science (Taylor & Cameron, 2016). Diwu and Ogunniyi (2012) add that some researchers believe that indigenous knowledge will not receive the necessary recognition in the classroom and will be marginalized. This will result in science being superior over indigenous knowledge (Taylor & Cameron, 2016). Cronje (2015) explains that sometimes indigenous knowledge is seen as unscientific and irrelevant to modern life, and this stigma of indigenous knowledge as “pseudo-science” should be addressed.

2. Exclusive perspective

Zinyeko et al. (2016) indicate that the second perspective weighs indigenous knowledge against scientific knowledge. The exclusive perspective sees indigenous knowledge and natural sciences as two different, independent knowledge domains. Some researchers believe that indigenous knowledge is a valid knowledge domain but is better on its own and not part of the science curriculum (Diwu & Ogunniyi, 2012). Such a perspective, therefore, advocates for the exclusion of indigenous knowledge in the school science curriculum. Figure 2 shows that each knowledge domain has unique tenets that make them special.
Figure 2: The exclusive perspective, highlighting the unique tenets of science and indigenous knowledge (Zinyeko et al., 2016; Cronje, 2015:37-41; Lederman et al., 2013:140-142)

Due to different tenets—specifically the holistic and metaphysical nature of indigenous knowledge—supporters of this perspective sometimes view indigenous knowledge as constituting “pseudo-science” (De Beer, 2016). Coker (2001:4) describes pseudo-science as having “no review, no standards, no pre-publication verification, (and) no demand for accuracy and precision”. Other scholars justify this exclusive perspective by stating that there are big differences in the epistemologies and methodologies of western science and indigenous knowledge (Onwu & Mosimege, 2004). Onwu and Mosimege (2004:6) state: “(V)erification methods and processes can be equated and be made to be similar standards, however, they have to be appropriate for each system, otherwise we would compromise one system at the expense of another and in the process lose the beauty of what the two systems could provide alongside each other”. This approach also eliminates the problem that teachers do not have the necessary knowledge or skills for such border-crossing, as they were not trained to integrate indigenous knowledge into their lessons (Zinyeko et al., 2016). Taylor and Cameron (2016) add that indigenous knowledge is better off as a separated knowledge domain to further enhance and appreciate its uniqueness.

3. Overlapping perspective (intersecting domains)

The third perspective’s intention is to bridge the gap between science and indigenous knowledge (Zinyeko et al., 2016). Figure 3 shows that this perspective acknowledges both the knowledge domains’ uniqueness and their similarities. This perspective celebrates both, the commonalities (shared tenets, e.g. both are empirical and inferential) and the uniqueness of each knowledge domain (e.g. indigenous knowledge is holistic and western science reductionist). In practice, this approach would mean that the focus in the classroom would be the shared tenets of the two domains.
These results in the two knowledge domains supporting and building on each other (Zinyeko et al., 2016). Taylor and Cameron (2016) believe that the distinction between the two types of knowledge domains is important in understanding the uniqueness of each knowledge domain. This perspective provides a place for indigenous knowledge in the school science curriculum.

An example of this approach would be the practice explained by De Beer and Whitlock (2009), whereby a teacher could contextualise a problem in terms of indigenous knowledge and expect the learners to use the processes of science to investigate the problem. How the efficacy of ‘muthi plants’ be tested in the classroom? De Beer and Whitlock (2009) describe an adapted Kirby-Bauer technique whereby learners can determine the antimicrobial properties of medicinal plants. Similarly, De Beer and Petersen (2017) explain how the ancient Chinese practice of burning incense to ripen fruit could be investigated in the school laboratory. Learners will have to formulate hypotheses and develop a laboratory protocol, to determine the influence of ethylene on plant growth. Criticism of such an approach would be that scientific processes are used to verify (accredit) indigenous knowledge. In this approach, the teacher should also acknowledge that aspects of indigenous knowledge (the metaphysical) fall outside the scope of science.

Benefits of using indigenous knowledge in the science classroom

From the study of Diwu and Ogunniyi (2012), it is clear that learning could be enhanced when it is contextualised by relevant and authentic indigenous knowledge. By using indigenous knowledge in the science classroom, contextual learning could be enhanced (Anazifa & Hadi, 2017). With the integrating of indigenous knowledge in the science classroom community values are furthermore emphasised (Anazifa & Hadi, 2017), thus promoting the affective domain. By incorporating indigenous knowledge into the science curriculum, science is better contextualised for diverse learners. However, the big cultural diversity among South African learners also poses problems for the teacher, as the question arises whose indigenous knowledge should be addressed in the classroom (Cronje, 2015). Teacher professional development is, therefore, of crucial importance, as teachers need to be shown how various indigenous knowledge systems could manifest in the science classroom (De Beer, 2019). Assignments should be given to learners to better understand the needs and reality of the local community (Shizha, 2012). For instance, De Beer and Van Wyk (2011) show how learners could engage in ethnobotanical surveys in the science classroom, but such an approach would only provide good results in communities where there exists sufficient ethnobotanical knowledge. Students’ learning can, therefore, be triggered by authentic problems in the local environment, and this could enhance awareness of the role of science in everyday life, and be the source of data for their assignments, investigations, and experiments (Shizha, 2012).
Disadvantages of integrating indigenous knowledge into the science classroom

According to Shizha (2012) teachers like to teach the empirical scientific knowledge to learners, and this knowledge is usually predetermined. In contrast, incorporating indigenous knowledge is not predetermined or given proper guidance to teach and so teachers find it difficult to teach. One of the disadvantages of integrating indigenous knowledge in the science classroom is that the planning and designing of teaching materials are time-consuming (Diwu & Ogunniyi, 2012), and generally there is a lack of teaching and learning resources. Anazifa and Hadi (2017) explain that teachers should be creative, full of initiative and rich in ideas, and they should also develop the necessary assessment opportunities to pay justice to indigenous knowledge systems. The development of these lessons takes extra time for teachers to plan. The availability of indigenous teaching materials complicates the teaching of indigenous knowledge (Shizha, 2012), and such epistemological border-crossing should receive more attention in both pre- and in-service teacher education.

CONCLUSION

The integration of indigenous knowledge into science themes (thus, better contextualisation of the curriculum) could result in learners developing an appreciation for the role of science in everyday life (Taylor & Cameron, 2016). Shizha (2012) believes that teachers often subconsciously incorporate indigenous knowledge into their lessons when using examples to explain or support scientific concepts and this can result in undervaluing indigenous knowledge. It is important that the incorporation of indigenous knowledge should also address the syntactical nature of science- not just the substantive nature (De Beer, 2019).

Zinyeko, et al., (2016) believes that the integration of indigenous knowledge into the school science curriculum is one way to maximize the socio-cultural relevance of scientific education and to improve learners’ performance. Balfour (2019) believes that the nascent scholarship on such epistemological border-crossing represents a powerful act of scholarly reclamation, restoration, and redress, which are so needed in the country. Therefore, there is a place for indigenous knowledge in the school science curriculum.

The three perspectives (the inclusive, exclusive and ‘overlapping domains’) on the role that indigenous knowledge plays in the school science curriculum are important in both pre- and in-service teacher education, as science teachers should develop nuanced understandings of the tenets of both indigenous knowledge and (western) scientific knowledge.

Acknowledgement

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ABSTRACT – The advocates for the infusion of indigenous knowledge in the school science curriculum often make a compelling argument that the natural sciences and indigenous knowledge share many tenets, and therefore such epistemological border-crossing could be facilitated with relative ease. Several scholars have shown how indigenous knowledge could be taught in the science classroom, utilising the processes of science. Joint tenets of science and indigenous knowledge include its empirical, inferential and tentative nature. However, the Achilles heel in this argument is how to deal with the metaphysical nature of indigenous knowledge in the science classroom. The ontological nature of science builds on the empirical-the universe is orderly and predictable. In contrast, indigenous knowledge has a dual ontological nature: it is both empirical and metaphysical. Most scholars would argue that the science teacher should only focus on the empirical component of indigenous knowledge, and ignore metaphysics, which is not aligned with the nature of the natural sciences. However, in doing so, indigenous knowledge is ransacked of its holistic nature. In this paper the author investigates examples of metaphysics in ethnobotany, and suggests that there often are plausible explanations for what, at first glance, might seem to be 'pseudo-science' or metaphysics. Furthermore, when learners engage with the more metaphysical aspects of indigenous knowledge, they are provided the opportunity to measure such practices against the accepted tenets of the natural sciences, and differentiate between science and pseudoscience. The paper also analyses contemporary research trends and career opportunities related to science with an indigenous knowledge imprint, and argues that the exclusion of indigenous knowledge in the school curriculum, based on its metaphysical dimension, would disadvantage learners. The inclusion of indigenous knowledge in the natural sciences curriculum will alert learners to both career and entrepreneurial opportunities that they may pursue in future.

Keywords: Indigenous knowledge, science education, metaphysical nature of indigenous knowledge, contextualising science, pseudo-science, career and entrepreneurial guidance.

INTRODUCTION

Authors such as De Beer (2016), De Beer and Petersen (2017) and Petersen, Golightly and Dudu (2019) suggest that indigenous knowledge could be included in the science classroom in a scientifically rigorous way, honouring the tenets of the natural sciences, such as its empirical, tentative and inferential nature. An example is where learners engage in an adapted Kirby-Bauer technique (De Beer & Whitlock, 2009) in the school laboratory, whereby they test the anti-microbial activity of medicinal (muthi) plants. In such an activity the processes of science are used to explore the rigour of indigenous knowledge. However, indigenous knowledge is holistic, and also includes metaphysical aspects that are difficult to understand. Ongunniiyi (2007:965) describes indigenous knowledge as ‘a conglomeration of knowledge systems’ that include science, religion, psychology and other fields. Based on these metaphysical aspects, many science educators advocate for the exclusion of indigenous knowledge in the school natural sciences curricula. Bringing the metaphysical dimension of indigenous knowledge into the science classroom, might easily promote pseudoscience. However, excluding indigenous knowledge might leave learners ignorant of a myriad of career and entrepreneurial opportunities that exist. This paper answers the question, ‘How could reference to metaphysical aspects of indigenous knowledge in the science classroom assists learners in developing more nuanced understandings of the nature of science?’

ON SCIENCE AND PSEUDOSCIENCE

Central to this paper, is the question whether indigenous knowledge should be seen as science or pseudoscience. Coker (2001:1) lists a number of characteristics of pseudoscience, namely that it displays an indifference to facts, that pseudoscience research is invariably sloppy, that it ignores criteria of valid evidence, it relies heavily on subjective
validation, it avoids putting its claims to meaningful testing, and that ‘pseudoscientists often appeal to an ancient habit of magical thinking’ (p. 4). Later on in this paper a case study is provided, and these features listed by Coker could be a good litmus test to distinguish between science and pseudoscience.

**METHODOLOGY**

With the national attention (e.g. fuelled by NRF initiatives) given to indigenous knowledge systems currently, there are many opportunities to firstly contextualise ‘western science’ to diverse South African learners in the science classroom, and also to provide them an overview of emerging career opportunities in the field of indigenous science. For this paper the author firstly analysed all the papers presented at the most recent Indigenous Plant Use Forum (IPUF) conference (7 – 10 July 2019, in Tshipise, Limpopo Province), to get a sense of the ethnobotanical-, ethnopharmaceutical and agricultural research that are being done, and the opportunities provided for a future generation of young scientists and entrepreneurs. IPUF is a unique conference which brings together researchers and practitioners, and the papers reflect cutting-edge research and latest trends. The author has analysed the 65 posters and research papers, using as criteria (a) science innovation that could supplement the CAPS curriculum themes; (b) indigenous knowledge that could better contextualise school science; (c) papers that could provide learners with more insight into the tenets of science; (d) entrepreneurial opportunities that could be explored in the classroom; and (e) possible career opportunities. Through this analysis the author shows why it is important for science educators to take note of the growing ethnobotanical and ethnopharmaceutical fields, and why this should also be incorporated in school science education. While listening to the papers, the author realised that the current school Life Sciences curriculum does not adequately prepare learners for the type of career opportunities that are emerging in the complex 21st century, and that, sadly, the majority of teachers do not have the knowledge to bring ethnobotany and ethnopharmaceutical research into their teaching. One of the reasons why such indigenous knowledge is often avoided, is the fear that pseudoscience might be promoted (Mothwa, 2011). If this is the case, it is important that classroom discussions on what constitutes pseudoscience should be conducted. The second part of the paper focuses on a few anecdotes on “magic” plants, and how there are often good scientific explanations for practices which seems to be, at first site, pseudoscience.

**NASCENT SCIENCE FIELDS: ETHNOBOTANY AND ETHNOZOOLOGY**

Sixty-five papers and posters were presented at the 2019 IPUF conference, and these were analysed to assess its relevance to the school Life Sciences, Physical Sciences and Natural Sciences curricula, and what affordances it holds for the classroom. We need to ask ourselves the question whether indigenous knowledge in the school classroom is portrayed as cutting-edge science, or whether lip-service is paid to indigenous knowledge through referring to an example of two. The analysis is shown in Table 1.

<table>
<thead>
<tr>
<th>Number of papers/posters</th>
<th>Central theme of paper/poster</th>
<th>Relevance to the natural science classroom</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Extraction methodologies, e.g. chromatography, the role of solvents, in ethnopharmacology studies. (Techniques for analysing active ingredients in plants have developed rapidly).</td>
<td>Metabolites are extracted by using sophisticated techniques, and these are relevant in several Life-, Physical and Natural Sciences themes. This is also an increasingly growing industry, with many career opportunities.</td>
</tr>
<tr>
<td>5</td>
<td>Testing the antimicrobial activity of plants (these include a wide variety of specialisations, e.g. the antimalarial activities of <em>Artemisia annua</em> (Anyomih, Kinfe &amp; Van Wyk, 2019); work on <em>Terminalia ferdinandiana</em> as a treatment</td>
<td>Links well with the microbiology section of the natural- and life sciences curricula. It also addresses sections in the curriculum on diseases such as malaria and AIDS. This is becoming an important industry in</td>
</tr>
</tbody>
</table>
for HIV/AIDS (Cock & Matthews, 2019); cancer studies; STD’s. terms of job creation. These insights might also show learners how science provides solutions to the biggest problems facing humankind (such as the AIDS pandemic).

| 3  | Safety and toxicity of plant extracts (this also includes issues of ethics, e.g. using animals such as Zebrafish (*Danio rerio*) in experimentation (Lepule, Mhlongo, Chipiti, Sowesa & Viljoen, 2019). | *Danio rerio* show a high genetic homology (70%) to humans, and can be used for experiments instead of rats or frogs. This addresses issues of ethics in the lab. It also provides many learners, who might consult traditional healers, with some of the problems with alternative medicines, such as dose and toxicity. |
| 12 | Food security and food cultivation (including environmental concerns, e.g. water use) | There is an international market for South African plant products. This growing field is creating many specialised career- and entrepreneurial opportunities. |
| 3  | Beverages (e.g. wine and beer) made from plants | South Africa has a high unemployment rate, and entrepreneurship should be encouraged amongst students. However, this theme also speaks to the curriculum content on anaerobic fermentation. |
| 3  | Plants and cosmetics | A theme that can be integrated in both life sciences and chemistry. Saponification can be easily explored in the science classroom, e.g. while making soap. |
| 14 | Ethnobotany of medicinal plants. Many South Africans rely on traditional healers for health care, and a large number of research projects are focusing on the efficacy of these medicines. | Not only can this be infused when dealing with the different body systems in life sciences, but learners can also develop more nuanced understandings of the nature of science- e.g. how is this research conducted? |
| 2  | Conservation of indigenous plants | Environmental conservation is a central theme in the curriculum. |
| 4  | Essential oils in plants | Essential oils are not just of medicinal importance, but also in the cosmetic industry. Many career- and entrepreneurial opportunities exist. |
| 8  | General ethnobotany and plant taxonomy | This relates well to the section on classification in the curriculum. |
| 2  | Ethnobotany and metaphysical aspects ("magic plants") | This provides learners the opportunity to engage with the nature of science. What constitutes “pseudoscience”? |
| 1  | Ethno-veterinary uses, such as medicinal plants used in curing cattle | Not only would this relate to many learners in rural areas (thus better contextualising the curriculum), but it also shows how our local flora hold promise as ethnoveterinary medicines. |
| 65 | | Table 1 shows that indigenous knowledge research could potentially open up many entrepreneurial and career opportunities for learners, and that care should be taken to not simply exclude indigenous knowledge due to its (sometimes) metaphysical dimension. While attending these papers during the IPUF conference, the author realised that, despite the fact that he quite recently (in 2012) obtained a MSc in botany, he would not be able to provide |
learners in school with an updated view on ethnobotanical developments. He simply does not have sufficient knowledge of this almost exponentially growing science. This made the author realise what injustice we do to school learners, as a large percentage of teachers do not hold postgraduate or recent qualifications in the natural sciences, and are most likely unaware of these developments. The danger exists that, in our ignorance of indigenous knowledge research, it gets labelled as ‘pseudoscience’, without taking cognizance of the sound science that often underpins it.

It would therefore hold much affordances if teachers could infuse these insights into their teaching. However, one of the categories listed in Table 1, is that of “magic plants”, and this warrants more attention.

“MAGIC PLANTS”: TO DEAL, OR NOT TO DEAL, WITH METAPHYSICS IN THE SCIENCE CLASSROOM

De Beer and Van Wyk (2019) provide an interesting example that could be dealt with in the life sciences classroom, related to the use of “magic” plants. These authors refer to the very poisonous creeper ‘impinda’ (*Adenia gummifera*), a plant which is commonly sold at traditional muthi markets. A decoction of the stems is traditionally used to sprinkle around the house, to inhibit ‘evil spirits’ (Van Wyk, 2015; De Beer & Van Wyk, 2019). Van Wyk shows that, in modern western households, bleaches and antiseptic products (e.g. Jik) are used for the same purpose, namely to inhibit the growth of micro-organisms. For indigenous knowledge holders, who are often illiterate, and who do not have microscopes to see micro-organisms, ‘evil spirits’ is the terminology used to describe the germs that cause diseases. Such people have realised that ‘impinda’ is an effective antiseptic (De Beer & Van Wyk 2019). Through careful observation indigenous knowledge holders have realised that impinda is a plant with strong antimicrobial properties, which could be used in household hygiene. By discussing this in the science classroom, learners will realise that there is nothing wrong with the science itself, but that it is more a question of terminology. (For illiterate people who did not have knowledge of pathogens, ‘evil spirits’ was the cause of disease). This example provides a good vehicle for learners to engage with the tenets of science.

AN INTERESTING CASE STUDY: AGRICULTURAL PRACTICES, MUSIC AND SEED GERMINATION

Learners should be critical consumers of science research. An interesting example to use in the science classroom, to discuss science and pseudoscience, is the influence of music on seed germination. In Maranao culture in the Philippines, rituals form part of agricultural practices. Planting activities (mainly rice) are accompanied by music, chanting, and dances (World Intellectual Property Organization, 2006; Dimaporo & Fernandez, 2007). The latter authors claim that these ceremonies are not simply superstitious cultural practices, but that there is a body of scientific literature that indicates that music has the potential to lead to better seed germination. It has been shown that sound, as an external factor, has a big influence on the biological index of plants (Bochu et al., 1998; Zhao et al., 2000; Chowdhury et al., 2014). Several studies have reported enhanced seed germination in various seeds when exposed to music. Although the influence of sound waves on plant tissues is still not well understood, several research studies provide evidence that sound waves influence plant cell morphology, biochemistry, and gene expression. Possible reasons for better seed germination when exposed to music given in literature include, among others, an increase in the concentration of metabolites (Chowdhury & Gupta, 2015); changes in the elastic modulus and the viscosity coefficient of the plasmalemma (Wang et al., 2001); an increase in intercellular Ca$^{2+}$ (part of the secondary messenger system) that can change the activity of membrane-bound enzymes (Wang et al., 2002; Teixeira da Silva & Dobránszki, 2014); and altering the secondary structure of cell wall proteins by changing amide I and amide II bonds (Chowdhury et al., 2014). It is important that students engage in the tentativeness of science as a tenet, by discussing this example. Many scientists do not agree with this claim that...
music could enhance seed germination, and critique is often that such studies were published in journals of questionable quality. The website Soundscapes (2015) traces this research back to the book, 'The secret life of plants' that was published in 1973, and which is criticized as promoting pseudo-science. By engaging in this conundrum, students will learn more about the tenets of the nature of science. The hypothesis that music could enhance seed germination could be accepted or rejected, based on evidence (the tentative nature of science). Furthermore, students will be able to get to a better understanding of how scientific research is communicated (in peer reviewed journals). De Beer (2019) shows that students (in cooperative learning fashion) could plan and execute experiments to test the influence (if any) of music on seed germination. This is a challenging assignment, due to the number of independent variables (different types of instruments and how they sound), dependent variables (rate of seed germination), and controlled variables (light intensity, temperature, water, etc.). In such epistemological border-crossing between natural science and indigenous knowledge, learners will come to a better understanding of the tenets of both science and indigenous knowledge. Learners will have to measure such research against the tenets of science (it is empirical, inferential, objective, etc), and also against the characteristics of pseudoscience as listed by Coker (2001).

CONCLUSION

The author is of the opinion that the metaphysical dimension of indigenous knowledge should not be completely ignored in the science classroom. Although the predominant focus should be on the shared tenets between science and indigenous knowledge (e.g. its empirical and inferential nature), the metaphysical component is a dimension of indigenous knowledge that should be acknowledged. By engaging with such metaphysical aspects, learners could develop more nuanced understandings of the nature of science, and to distinguish between science and pseudoscience.

It is recommended that in-service training opportunities should be provided to natural- and life sciences teachers, in order for them to infuse these new developments in ethnobotany and ethnopharmacology in the classroom. South Africa could learn from the ‘Target Inquiry at Miami University’ (Mackenzie, 2001), an initiative that focussed on creating authentic laboratory learning experiences for science teachers. Such knowledge and skills would assist teachers to mainstream the affective domain, and alert a young generation of novice scientists of the career and entrepreneurial opportunities that science and indigenous knowledge hold.

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LEARNERS’ PERCEPTIONS ABOUT THE INTEGRATION OF THEIR SOCIO-CULTURAL BELIEFS IN LIFE SCIENCES

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ABSTRACT – Culturally responsive science teaching and learning has been a subject of intense discussion among researchers on pedagogy the world over. This study explores learner perceptions about the inclusion of their socio-cultural beliefs in the teaching and learning of particular Life Sciences topics. It presupposes that the integration of learners’ socio-cultural beliefs in certain Life Sciences concepts is likely to motivate learners to engage fully in the learning process as they find relevance of what they learn in their lives. The study employed both quantitative and qualitative research designs. A questionnaire comprising closed and open questions was administered to 166 Grade 10 and 11 Life Sciences learners in seven high schools in Johannesburg. The learners belonged to diverse religious affiliations and races, which provided a rich ground for diversity in learner perceptions. The majority of learners perceived the incorporation of cultural beliefs in learning particular Life Sciences topics as important. The findings however indicate that learners were conflicted when the integration concerns topics embedded with socio-scientific issues such as reproduction, genetically modified foods, cloning, organ transplants and donation. Some learners did not perceive the integration as worthwhile since their goal for learning Life Sciences was to acquire scientific knowledge. It can be concluded and recommended that teacher professional development should continue to equip Life Sciences teachers with skills to deal with such diverse learner perceptions in the classrooms.

Keywords: Socio-cultural beliefs, learners’ perceptions, Life Sciences.

INTRODUCTION
Contextually appropriate science education has been advocated for many decades. By relating the content to be learned in the science classroom with the learning experienced in learners’ cultures, has been regarded as the most effective way to contextualise the teaching of science (Reyhner, Gilbert & Lockard, 2011). Incorporation of learners’ socio-cultural beliefs in Life Sciences teaching and learning helps to affirm learners’ identity as members of the learning community. Due to urbanisation, foreign value systems may threaten, modify, enhance, replace or corrupt the cherished value system of an indigenous group of people. As such, it is critical to involve learners in making decisions on the what, how and why of their socio-cultural beliefs that should be integrated in science teaching and learning. Consequently, the purpose of this study was to determine learners’ perceptions on the inclusion by educators of learner socio-cultural beliefs in some Life Sciences topics during the learning milieu. Socio-cultural beliefs refer to a set of common norms and values a certain group of people uphold in their day to day living.

THEORETICAL BACKGROUND
The study uses the framework on cultural influences in education as adapted from the Hawaai theoretical model (Ledward & Takayama, 2008). Figure 1 shows the model.
The framework explains the interrelationships that exist between different knowledge domains, how they influence learner engagement and ultimately determine learner performance and achievement in Life Sciences. The study assumes that the beliefs learners hold about a particular Life Sciences concept or process are the lens learners use to determine how worthy they are in the classroom. This style by the learners will in turn impact immensely on how they participate, accept and understand what they learn.

In the Life Sciences curriculum document, the Department of Basic Education (2011) defines Indigenous Knowledge Systems (IKS) as ‘a body of knowledge embedded in African philosophical thinking and social practices that have evolved over thousands of years’ (p. 5). The learners’ socio-cultural beliefs herein referred to in the current study falls in the IKS domain. The current study premises on the fact that when learners’ socio-cultural backgrounds are integrated in the Life Sciences classroom, it is likely to positively influence learners’ socio-emotional development and academic outcomes. Learners fail to decipher meaning from classroom learning activities, whose content is divorced from their culture. Demmert (1999) describes such classroom environments as providing decontextualized and one-size-fits all science material. There is limited research that has investigated how learners interpret and perceive the relationship between indigenous knowledge and western science (Gondwe et al. 2014). Consequently, the current study intends to answer the research question: How do learners perceive the integration of their socio-cultural beliefs in some Life Sciences topics during the teaching and learning process?

**METHODOLOGY**

The study employed both quantitative and qualitative research designs (Creswell, 2014). This is appropriate as the combination of the dual strengths of both quantitative and qualitative research methods compensate for the individual limitations of the respective designs. (Pluye & Hong, 2014). Using Patton’s (2002) notion of selecting appropriate sample for a study, seven different high schools in Johannesburg were randomly selected. All Grade 10 and 11 Life Sciences learners from the schools (n=166) participated in the study. Table 1 shows learner profiles.

<table>
<thead>
<tr>
<th>GENDER</th>
<th>FEMALES</th>
<th>MALES</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>RACE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLACK</td>
<td>117</td>
<td>18</td>
</tr>
<tr>
<td>WHITE</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>INDIAN</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>COLOURED</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>RELIGION</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHRISTIANITY</td>
<td>105</td>
<td>17</td>
</tr>
<tr>
<td>HINDU</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>MUSLIM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AFRICAN TRADITION</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>TOTAL NO. OF LEARNERS</td>
<td>166</td>
<td></td>
</tr>
</tbody>
</table>

Data collection involved the administration of a questionnaire which sought both learner understandings of the role played by the inclusion of their socio-cultural beliefs in the teaching and learning of Life Sciences topics and how this influenced the learners’ understanding of the concepts. The questionnaire comprised two sections, the quantitative section and the qualitative section. The quantitative section with Likert scale (agree, neutral and disagree) required learners to indicate how they perceive biological practices such as abortion, cloning and organ transplantation in relation to their socio-cultural beliefs in order to answer the research question: How do learners perceive the integration of their socio-cultural beliefs in some Life Sciences topics during the teaching and learning process? Example of a statement learners needed to respond to was: Relating content on abortion to my cultural practices and beliefs helps me in applying the content. The above Life Sciences topics were selected because they are considered to be contentious as they invoke learners’ belief systems. The qualitative section provided learners with an opportunity to explain and elaborate on their perceptions in order to determine how those perceptions are informed by their socio-cultural beliefs. For reliability purposes, the questionnaire was first piloted to a
group of 20 MEd Science students and 20 Third Year Life Sciences Methodology students. Certain questions were removed and others were modified based on the responses from the analysis of pilot data. Quantitative data was analysed using SPSS version 25 and qualitative data was subjected to content analysis with the aid of Computer Assisted Qualitative Data Analysis Software (CAQDAS) like atlas ti. 8. Due to the scope of the paper, only findings of learners’ perceptions on the integration of their socio-cultural beliefs in the teaching of some Life Sciences topics are presented.

RESULTS

Analysis of data from quantitative and qualitative responses from 166 learners shows that the majority of learners perceive the incorporation of cultural beliefs when learning particular Life Sciences topics as important. The findings however indicate how learners were conflicted when the topics to be integrated with their socio-cultural beliefs, are embedded with socio-scientific issues. Examples of such topics were reproduction, genetically modified foods, cloning and organ transplants and donation. Socio-scientific Issues (SSIs) are controversial, socially relevant and real-world problems that are informed by science and often include an ethical component (Zeidler & Nichols, 2004). This calls for appropriate teacher pedagogical practices when teaching such topics. Table 2 and 3 show the distribution of learners’ perceptions regarding the different Life Sciences concepts in which their beliefs could be integrated.

Learners’ perceptions about topics where incorporation of cultural beliefs can be done

Learners had various perceptions regarding the topics which teachers could use in incorporating their cultural beliefs as shown.

Table 2: Learners’ perceptions about topics where incorporation of cultural beliefs can be done

<table>
<thead>
<tr>
<th>Life Sciences topics</th>
<th>Agreed</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Disease and issues of traditional medicine</td>
<td>63.5</td>
<td>27.7</td>
<td>9</td>
</tr>
<tr>
<td>2. Human impact on environment and conservation</td>
<td>55.4</td>
<td>30.7</td>
<td>13.9</td>
</tr>
<tr>
<td>3. Biotechnology: GMOs and cloning</td>
<td>44</td>
<td>28.3</td>
<td>27.7</td>
</tr>
<tr>
<td>4. Circulatory system: Blood transfusion</td>
<td>54.2</td>
<td>36.7</td>
<td>9</td>
</tr>
<tr>
<td>5. Excretory system: Organ transplant/donation</td>
<td>49.4</td>
<td>39.8</td>
<td>10.8</td>
</tr>
<tr>
<td>Average</td>
<td>55.2</td>
<td>32.6</td>
<td>14</td>
</tr>
</tbody>
</table>

From the findings in Table 2, it shows that the majority of learners (63.5%) agreed that their socio-cultural beliefs should be integrated in the teaching and learning of diseases and issues of traditional medicine. This is consistent with previous studies which showed that in Africa, 80% of the population uses traditional medicine (Geneva, World Health Organisation, 2001). Further, similar studies have found that the use of traditional medicine remains popular in most regions of the developing world even amongst people with access to modern health facilities (Gari, Tarlagadda & Wolde-Mariam, 2015). Another important reason for such high preference of traditional medicine lies in the belief that such medication can treat illness from both mystical and natural causes (Bishaw, 1991). In their responses to open-ended questions, learners demonstrated how their belief systems influence the way they perceive Life Sciences teaching and learning practices in their classrooms.

Learners’ reasons for their perceptions

A good number of learners (49.4%) who agreed to the incorporation of their cultural beliefs in specific Life Sciences topics such as organ transplant/donation, indicated in the open-ended questions why such integration was important to them. When responding to issues about the excretory system and associated concepts such as kidney diseases and transplant, some of the learners expressed the belief that diseases of the kidneys are caused by witchcraft. An example of one learner’s response was, “People bewitch innocent others, for example the kidney stones, how can one grow stones in the body? Obviously witches planted the stones
in the body”. Such a response shows how learners are ingrained in their belief systems, which can interfere with their understanding of scientific concepts if such misconceptions are not appropriately dealt with during the teaching and learning process. In this case, there is a likelihood of learners always finding an easy way to explain phenomena by blaming it on witchcraft instead of exploring the logical scientific reasoning.

Learners had diverse perceptions regarding the practice of organ transplant. Some learners indicated that the process can help in prolonging the lives of people especially if it is the last resort as saving life is more important than considering one’s beliefs. On the other hand, there were learners with strong religious beliefs, who viewed it as a practice of interfering with the natural process of creation. When referring to the process of dialysis, learners wrote,

Learner 1: What it means is if God wants a person to die, the person must accept fate and not survive under machines.

Learner 2: “You will die when you are meant to die and if your kidneys fail it is a sign. There were learners whose responses had an ethical angle as they pointed out that death is unconceivable to humans hence it could be possible that when an organ is harvested from a dead person, his/her ‘soul’ might feel pain. Others pointed out that there is need to respect the dead by burying them when their bodies are intact. Learners who held strong traditional African beliefs, felt that it was not acceptable to implant an organ from one person to another particularly amongst people who are not of the same family. One learner responded, “You cannot mix blood”. These learners revealed their beliefs by arguing that an incomplete person (referring to the organ donor) could not be accepted by the ‘gods’ after death, so the person’s spirit would roam around on earth. Another argument why some learners’ cultures forbid transplants was that both the donor and the recipient would not be recognised by their ancestors which would lead to them not being at rest after death. These learners believed in the supernatural powers as explained by Wallace (2015) who contends that one central belief of the African worldview is based on the continuous role by ancestors in protecting, guiding and admonishing both the living and the dead.

Cloning proved to be a contentious concept in Life Sciences as it invoked the learners’ belief systems. Indeed, some learners condemned the cloning of organisms indicating that species should be brought to earth naturally. These learners’ reasons were that God gives life and therefore cloning shows defiance against the special creation, which should be the preserve of God alone. As such, only 44% of the learners agreed to have their belief systems incorporated when learning the topic cloning, which is against 28.3% who were neutral and 27.7% who did not agree. Generally, most learners from Christian and Muslim religions expressed their belief in God.

The extent of some of these learners’ faith in their religion is portrayed in some of the examples they wrote. For instance, one learner pointed out that any illness or any disease infection happens because God has allowed it. They indicated that only prayer could heal the sick or cure diseases no matter what type of diet one follows. There were learners who even mentioned that they lost their loved ones who did not seek any medical help because their religion does not encourage clinical treatment. Based on these findings, Life Sciences teachers need to utilise teaching strategies which help to deal with such beliefs without necessarily undermining them. By ignoring such beliefs, acquisition of concepts such as disease causing microorganisms covered in Grade 11 and the issue of immunity that is handled in Grade 10 would be compromised. The role of the teachers is to employ pedagogical strategies which enable learners to realise the conflict between their beliefs and the scientific concepts then assist learners to correctly decipher the best explanation of the phenomena. Table 3 shows learners’ perceptions about the integration of their socio-cultural beliefs and various concepts under the topic reproduction.
Learners’ perceptions about integrating socio-cultural beliefs and reproduction

Learners showed different perceptions regarding the suitability of certain concepts on reproduction for integration with their socio-cultural beliefs during the teaching and learning process.

Table 3: Distribution of learners’ perceptions about the integration of socio-cultural beliefs and reproduction

<table>
<thead>
<tr>
<th>Concepts on reproduction</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menstrual cycle</td>
<td>54.8</td>
<td>41.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Abortion</td>
<td>41</td>
<td>35.5</td>
<td>23.5</td>
</tr>
<tr>
<td>Contraceptives</td>
<td>48.8</td>
<td>38</td>
<td>13.3</td>
</tr>
<tr>
<td>Circumcision</td>
<td>57.8</td>
<td>35.5</td>
<td>6.6</td>
</tr>
<tr>
<td>Average</td>
<td>50.6</td>
<td>37.7</td>
<td>11.7</td>
</tr>
</tbody>
</table>

The topic reproduction proved to evoke emotions in most learners when it came to its integration with their socio-cultural beliefs. An average of learners who agreed to the integration of their beliefs in the teaching and learning of reproduction (50.6%) is lower compared to the average of 55.2% in Table 2 where learners agreed to the integration of their beliefs with other topics. Abortion had the lowest percentage of learners who agreed (41%) and had the highest percentage of learners (23.5%) who disagreed to integrate the topic with their socio-cultural beliefs, which is double the average under that category (11.7%). In response to the open-ended question which required them to explain how they perceived the different processes they study in Life Sciences, some of the learners indicated the following:

Learner 1: Abortion is a sin because you are killing an innocent child.
Learner 2: Abortion is wrong because killing is against the universal rights, everyone has a right to life no matter the circumstances.

There were other learners who, despite their beliefs, complimented the government for ‘decriminalising abortion’. These learners’ sentiments are supported by Jewkes and Rees (2005) study where they found a decline in abortion-related deaths (91%) since 1994. These learners were focusing on the reality of the life they live as teenagers. As such, their responses were emotive and empathetic to their peers who fall pregnant. Some of the reasons given were that abortion is necessary to pregnant teenagers; it is inevitable as it would enable the girls to continue with their studies; that such teenage girls would not be ready to be parents; and that the girls should not be held accountable because the circumstances that caused them to be pregnant could be beyond their control. One learner responded, “what if the girl was raped or has no access to contraceptives?” This is a very pertinent question in a society where parents are not comfortable to discuss issues of sexuality with their children. This has pedagogical implications on Life Sciences teachers to assume new roles because Irvine (2003) suggested that successful teachers of culturally diverse learners should adopt parental/surrogate roles with their learners in order to build cultural competence.

In as much as an average 55.2% (Table 2) and 50.6% (Table 3) of the learners agreed that certain topics require integration with socio-cultural beliefs, there were some who were neutral (32.6% and 37.7%) and those who disagreed (14% and 11.7%) in Table 2 and 3 respectively. The main reason given by those who disagreed was that Life Sciences, like any other science is a concise and empirical truth. Examples of what some of the learners wrote was, “We need not pollute science with culture or opinions; Integration merely hinders progress”. Such learner perceptions defy the principles underpinning the nature of science and these learners may fail to conceptualise Life Sciences concepts appropriately. Therefore, teachers should employ pedagogical activities such case studies, that engage learners in
application of what they learn in everyday life. In this way, learners may appreciate the relationship between science concepts and their belief systems.

DISCUSSION OF RESULTS

The findings show that learners appreciate and value the importance of integrating their socio-cultural beliefs in the Life Sciences classroom, particularly when dealing with topics embedded with different socio-scientific issues that directly affect the learners. Baker and Taylor (1995) posit that learners can make the best out of their worldviews in learning scientific concepts provided teachers utilise constructivist teaching strategies that recognise the important role of learners' prior knowledge. As early as 1982, Gilbert, Watts and Osborne noted that learners' prior understandings influence their interpretation of new learned information. As such, the findings of the current study showed how learners because of their strong beliefs failed to accept organ transplants, and how the topic reproduction (e.g. abortion and contraception) and cloning evoked emotions in most learners. These learners did not give room for proper conception of new scientific concepts because of what they already knew based on the belief systems. This is because beliefs are enduring since they cannot be easily changed, hence Pajares (1992) described them as deeply personal, rather than universal, and unaffected by persuasion. Though Pajares was referring to teachers' beliefs, this also applies to learners' beliefs. It there calls for Life Sciences teachers to apply pedagogical strategies that engage learners in a process of reflection. Previous researchers (e.g. Driver, Newton & Osborne, 2000) advocated for the use of argumentation, discourse and case studies to enable the learners seek evidence, engage in critical thinking and make informed decisions when dealing with diverse socio-scientific issues. Because the Life Sciences concepts dealt with in this study evoked emotions amongst learners from varied belief systems, argumentation would provide an opportunity for learners to explore divergent ways of viewing a phenomenon in order to reach a consensus. When learners are involved in dialogue, they gain scientific literacy through the debating on issues and sharing of their multiple views based on competing and conflicting evidence (Zeidler, Walker, Ackett & Simmons, 2002). In this way, explicit connections between learners' beliefs and the nature of science are likely to be revealed to and conceptualised by learners (Zeidler, et al., 2002).

CONCLUSION

There were three main findings from this study which answered the research question: How do learners perceive the integration of their socio-cultural beliefs in some Life Sciences topics during the teaching and learning process? Firstly, the majority of learners perceived the incorporation of cultural beliefs when learning particular Life Sciences topics as important. Secondly, the findings indicate that learners were conflicted when the topics to be integrated with their socio-cultural beliefs, are embedded with socio-scientific issues. Examples of such topics were reproduction, genetically modified foods, cloning and organ transplants and donation. Thirdly, some learners did not perceive the integration as worthwhile since their goal for learning Life Sciences was to acquire scientific knowledge. Based on the theoretical framework used in the study (Fig.1), indeed the findings show the relationship between learners' belief systems and Life Sciences concepts. The diverse views learners brought up, for example, in relation to the incorporation of their socio-cultural beliefs in such concepts like abortion, cloning and organ transplant should inform teachers' pedagogical practices. Because some learners were explicit in expressing how abortion for instance, conflicts with their beliefs, it is imperative that teachers employ strategies and assign activities that engage learners fully in discussion to develop critical thinking skills. The study suggests argumentation and case studies as platforms through which learners can explore their different viewpoints and then make informed decisions regarding such contentious science phenomena.

The study has methodological limitations in that classroom observations of the actual teaching and learning process were not done, which could have yielded important information on learner engagement. Moving forward, the researcher recommends classroom
observations and interviews for both teachers and learners for future studies. Ultimately, the findings reiterate the need for a continued teacher professional development that focuses on integrating learners’ socio-cultural beliefs and practices in the teaching of particular Life Sciences concepts in order to make science interesting and relevant to the learners’ lives.

REFERENCES
Pajares, M. F. Teachers' beliefs and educational research: Cleaning up a messy construct. Review of Educational Research, 63(3), 307-332.
ABSTRACT: In this paper, we report on an investigation regarding teaching strategies used by mathematics teachers and their thoughts in facilitating learning for learners with difficulties in learning mathematics. This study adopted an observational approach and open-ended post observation questionnaires with four primary school teachers. The results revealed that from all five teaching strategies, all teachers tend to use scaffolding and argued that they prefer explicit instruction. Those that attempted to use problem-solving strategy always guided learners. It was also found that teachers with special needs training used concrete objects when introducing lessons. The results also reveal that experienced teachers and those with special needs training used most of the teaching strategies successfully. Our conclusion is that all mathematics teachers (at special schools and mainstream schools) who teach learners with special educational needs (LSEN) must be well trained in the area for special needs education including the use of all teaching strategies before introducing inclusive schools.

Key words: teaching strategies; learning difficulties; special needs education

INTRODUCTION AND BACKGROUND

Since 1994 the government has been committed to building an inclusive education system (inclusion of learners of different races, classes, or religion, and also of learners with different mental and physical abilities) with the intention of accommodating as many learners as possible, including those experiencing different kinds of barriers to learning, in inclusive mainstream schools (DoE, South Africa, 2001). In this context, a public-private partnership was set up in the late 2000s that established a small number of research and development Chairs, based in South African universities aimed at developing and studying the implementation of research-based interventions to improve learning outcomes.

In South Africa, schooling is divided into mainstream education and special needs education. The intention of the government is that special needs schools must serve as resource centres for inclusive mainstream schools (DoE, South Africa, 2001). As it is Internationally, inclusive education in many countries of the Global North has developed in the early 70s from a foundation of well established special education systems (Walton, 2018). With well developed special education system, the assumption is that teachers in special needs schools must have specialised knowledge, experience and training to use teaching strategies that are effective for teaching learners with learning difficulties. Teachers can acquire specialised knowledge if they are trained as it is internationally. According to Mbengwa (2010), when implementing inclusive education internationally, teacher education realised a move from special needs as an area of specialisation to the ensuring that all teacher education should include special needs training. We concur with Mbengwa (2010) and suggest that such training be included in the programmes for undergraduate and post graduate courses for those who are intending to teach mathematics at schools and post-school, and to those teachers that have been at the schools for many years.

We argue that, before planning to have inclusive schools in South Africa, it is necessary to investigate teaching strategies used by mathematics teachers at schools for learners with learning difficulties in different subjects, and in particular for specialised subjects like mathematics which are challenging to both teachers and learners. It must be noted that the term learning difficulties is used differently in other countries. For an example, in the UK, the term learning difficulty refers to children and young ones with specific learning difficulties. while in the US and Australia they refer to the term learning disabilities, which is equivalent to learning difficulties. For the context of this study, we will use the term learning difficulties,
with no intention to categorise learners due to the different disabilities. We assume that learners that are enrolled at Special Schools experience intrinsic barriers to learning. The research question for this study is: Which teaching strategies are used by mathematics teachers for learners with learning difficulties in mathematics and their thoughts in facilitating learning?

LITERATURE AND THEORY
Mercer, Mercer and Pullen (2014) argue that special needs educators are confronted with different kinds of learning difficulties ranging from mild (minor reading difficulties or mild dyslexia) to severe (severe dyscalculia or brain injuries). Learners with learning difficulties experience intrinsic barriers to learning that can impede their understanding or application of mathematical concepts. These barriers to learning include difficulties in respect of memory, attention span, processing, language, metacognitive thinking, as well as maths anxiety, learned helplessness and passivity (Allsopp, Kyger & Lovin, 2007; Dednam, 2011). Mathematics teachers and these learners are confronted with these barriers every day in the classroom. In order to enable learning, teachers cannot rely on only one type of teaching approach (Mercer et al., 2014).

Teaching strategies used mainly in special needs education are explicit and implicit instruction (Mercer et al., 2014; Lerner & Johns, 2012; Allsopp et al., 2007). With explicit instruction (direct instruction associated with behaviourism) the teacher provides an explanation or demonstrates a skill or concept in different contexts and then provides opportunities for independent practise by learners to ensure mastery of that particular skill or concept, by contrast, implicit instruction (associated with constructivism) emphasises the development of learner thinking processes (Mercer et al., 2014). Mercer et al. (2014) and Allsopp et al. (2007) believe that when learning is difficult, the teacher should provide extensive support, where the two strategies are integrated in the form on interactive instruction where instruction is based on guided discovery in a form of a dialogue between the teacher and the learner, called scaffolding.

The three key features of interactive instruction are explicit teacher demonstration (I do it), guided practice (we do it) and independent practice (you do it) (Mercer et al., 2014; Miller & Hudson, 2006). For the purpose of this study, five teaching strategies were identified from literature as follows: teaching within an authentic context, building meaningful connections, scaffolding, concrete representational abstract sequencing and problem-solving strategies (Allsopp et al., 2007; Lerner & Johns, 2012; Miller & Hudson, 2006; Mercer et al., 2014). It is important to note that these five teaching strategies are universal and useful in all teaching situations and not just for learners with learning difficulties. However, researchers who focus specifically on mathematics education involving learners with learning difficulties emphasise the importance of using these strategies.

Authentic context (AC). Teaching within an AC demonstrates to learners the relevance of mathematics in their daily lives, such as using the example of cutting a cake into equal smaller pieces when explaining fractions. With AC learners get an opportunity to link what they learnt to other contexts. In that case, AC help build meaningful connections.

Building meaningful connections (BMC). Learners bring prior knowledge that can either enable or impede learning. Prior knowledge can also influence how learners will organise and interpret new knowledge. The teacher should assist learners to make connections between what they already know and the new mathematical concept that is being learned (Nel & Nel, 2012). For example, the teacher could remind learners about how fractions with different denominators are added before explaining how mixed numbers with different denominators should be added.
**Scaffolding (SC).** With scaffolding, a learner is assisted by a teacher to complete a task that is beyond the learner’s ability (Gultig & Stielau, 2012). According to Miller and Hudson (2006) the scaffolding process follows a sequence of ‘I do’ by the teacher; followed by ‘we do’ by the learner through teacher’s guidance; and then ‘you do’ by learner alone. At the ‘I do’ stage, the teacher demonstrates how to solve a problem, at the ‘we do’ stage, the teacher will do work together with the learners. Lastly, in the ‘you do’ stage, the teacher will allow learners to solve problem solve by themselves.

**Concrete representational abstract sequencing (CRAS).** Researchers who studied the use of CRAS, specifically in LSEN schools argue that when teaching learners with learning difficulties, it is important to start at a concrete level (involving real objects), proceed to the representational level (involving pictures) and only then progress to the abstract level (mathematical symbols) to ensure that they understand (Lerner & Johns, 2012; Mercer et al., 2014; Allsopp et al., 2007; Miller & Hudson, 2006), since learners with learning difficulties have problems with abstract thinking. CRAS helps learners to build meaningful connections with previously learned work, it can be used in the scaffolding process, and it helps with problem-solving skills.

**Problem-solving (PS).** According to Polya (1957) problem-solving consists of four stages: the learner: recognises and understands the problem and identifies what is required to solve it; understands how the different items in the problem are connected and plans a procedural approach; decides on the mathematical knowledge required to solve the problem and solves it; and considers the answer and decides whether it makes sense or not. Problem-solving in mathematics is an important skill to master, but it is also complex. Unfortunately, many learners with learning difficulties have a problem in this area (Lerner & Johns, 2012).

Even if we have identified the above strategies to use, some researchers believe that the problem is far-fetched. These researchers argue that as we strive to build an inclusive education system for all, the focus should not be on trying to assist students with mathematics learning disabilities, the focus should rather be on “how we can learn to build a mathematics education system that no longer disables so many mathematics students” (Scherer, Beswick, DeBlois, Healy & Opitz, 2016, p. 646).

When introducing the Universal Design for Learning (UDL), Dalton, McKenzie and Kahonde (2012) suggest that teacher training should implement UDL since it addresses the needs for a more flexible curriculum and may deal with teachers’ lack of knowledge and skills. The aim of UDL according to Dalton et al. (2012) is therefore to lower learning barriers and to include learners (with or without learning difficulties) in the learning process.

**METHODS AND SAMPLING**

In this study, four primary school teachers (all with appropriate teacher qualifications) were selected using purposive maximum variation sampling. A structured questionnaire was designed to cover two criteria. We considered participants’ years of teaching experience in special needs schools and the participants formal training in special needs education (learning support). Two teachers had different combinations: Less than three years teaching experience, Inexperienced (I) and either with special needs training (ST) or did not have special needs training (NT). The other two teachers had different combinations: More than 10 years teaching experience, Experienced (E) and either with special needs training (ST) or did not have special needs training (NT). For example, from Table 1, Teacher 2 had two years teaching experience and had special needs training (T2(I/ST)). The teachers with special needs training had different qualifications. Teacher 2 had a PGCE diploma (majoring in Inclusive Education) and was busy with a BEd Honours degree (Remedial Education and Learning Disabilities) during the data collection period. Teacher 4 had a diploma in Minimum
Brain Dysfunction. Other noteworthy information from Table 1 is the difference in age of the teachers (27 to 53 years) and the different grades they taught (Grades 4 to 7).

### Table 1: Description of participants

<table>
<thead>
<tr>
<th></th>
<th>Teacher 1 T1(I/NT)</th>
<th>Teacher 2 T2(I/ST)</th>
<th>Teacher 3 T3(E/NT)</th>
<th>Teacher 4 T4(E/ST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>27 years</td>
<td>30 years</td>
<td>57 years</td>
<td>53 years</td>
</tr>
<tr>
<td>Grade taught</td>
<td>Grade 6</td>
<td>Grade 5</td>
<td>Grade 7</td>
<td>Grade 4</td>
</tr>
<tr>
<td>Teaching experience</td>
<td>1.5 years</td>
<td>2 years</td>
<td>11 years</td>
<td>22 years</td>
</tr>
<tr>
<td>Special needs training</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

A structured observation schedule was used to record four lessons taught by the four teachers over a period of three weeks. The class size was ranging from between 10 to 24 learners. Though not the focus of this study, we noted that there were two to five learners in some classes who used computers for writing. These learners had cerebral palsy or low muscle tone which prevented them from writing properly with their hands. They also had assistant teachers. The collected data was categorised according to the five teaching strategies that were identified from the literature and analysed. Space was provided for other strategies that could emerge during the observations. After observations, a semi-structured questionnaire was used with all teachers (based on their thoughts).

### RESULTS BASED ON OBSERVATIONS

The results revealed that T4(E/SP) used four strategies effectively in all her lessons, except problem-solving strategies that was used through teacher guidance. T1(I/NT) did not use concrete objects in all four lessons; taught abstractly and used authentic context averagely. The way she taught could be as a result of her lack of teaching experience and no special needs training. All the teachers used scaffolding in all lessons. However, none of them taught problem-solving strategies without guiding learners or using rules. One would expect that T4(E/SP) with all her experience and training in special needs education would make use of problem-solving strategies without guiding learners. For the scope of this paper, we report in depth on observations for T2(I/SP) and T3(E/NT) because their results for the use of the five teaching strategies were much similar. They had different teaching experiences. Teacher 2 had special needs training. What each teacher said in class is written in italic.

Cases: T2(I/SP) and T3(E/NT)

**Authentic context** was used twice by T2(I/SP). In Lesson 1 example of slices of pizza and a bar of chocolate were used to revise fractions. T3(E/NT) used authentic context in three of her four lessons. For example, in Lesson 1 the idea of equivalent fractions was used by giving three learners all R10 but in different formats; one learner received a R10 note, another learner received two R5 coins and the last learner received a R5, two R2 and one R1 coin.

**Building of meaningful connections**, was used three times by T2(I/SP) and twice by T3(E/NT). During Lesson 2, T2(I/SP) revised addition and subtraction of fractions with the same denominator before teaching addition and subtraction with different denominators. In Lesson 4, T2(I/SP) asked learners to explain what whole numbers and fractions were, before explaining the concept of mixed numbers. In Lesson 4, T3(E/NT) reminded learners of the addition and subtraction of fractions and explained that one of the first steps was to change mixed numbers into improper fractions. This also applies when we multiply fractions, but we do not have to calculate the LCD (lowest common denominator) when we multiply fractions.

**Scaffolding** was used predominantly. Both T2(I/SP) and T3(E/NT) used scaffolding in all their lessons. In Lesson 2 for example, T2(I/SP) did various mathematical problems with the learners, reminding them of the following golden rules: *The denominator have to be the
same, and everything you do at the bottom you must also do at the top. Learners were then
given an opportunity to solve a problem with the teacher. Thereafter the teacher handed out
a worksheet that learners had to complete on their own. When they struggled to complete the
worksheet, she assisted each learner individually by pointing out their mistakes. In Lesson 3,
T3(E/NT) explained how two fractions with different denominators had to be added together
and gave a step-by-step demonstration to show the learners how to solve the problem.
Example: \( \frac{2}{3} + \frac{4}{9} \). While she was explaining the problem, she asked the learners many
questions, for example: Can I add the two fractions? What do I need to do now? She then
showed that the LCD was required first: \( M_3: 3, 6, 9, 12, 15 \) and \( M_9: 9, 18, 27 \), therefore the
LCD is 9. Using a coloured pen, she added the multiplication: \( \frac{2}{3} \times \frac{3}{3} + \frac{4}{9} \). Afterwards one of the
learners was invited to be the teacher. The learner had to explain what he was doing and
was also allowed to ask the other learners what he should do when he did not know how to
continue. The teacher helped him from time to time by telling him what type of questions he
should ask the class.

With Concrete-representational-abstract sequencing, the results were interesting. T2(I/SP) used the
CRAS in only two of the four lessons, whereas T3(E/NT) used the concrete-representational-abstract sequencing only once. In Lesson 1, T2(I/SP) asked the
learners the day before to bring paper plates to class to represent a Pizza activity. These
plates were cut up into halves, quarters and eights (concrete level) (Figure 1). The teacher
drew a pizza on the board and divided it into halves, quarters and eights (representational)
and then wrote the corresponding abstract symbol on each paper plate piece and on the
representation on the board. T2(I/SP) used representational-abstract sequencing once and
once taught only abstractly. In Lesson 4, she continued to use the plates from Lesson 1 to
move from the representational level (pictures as in Figure 2) to the corresponding abstract
level when writing the mixed number in symbol form as \( 1 \frac{1}{2} \) and \( 4 \frac{3}{4} \). In this fraction activity,
the teacher made connections from a circular shape to a shape that resembles a square.

T3(E/NT) gave each learner different wooden or plastic pieces (in Lesson 1) that represented
fractions that they had to manipulate before she drew diagrams on the board and wrote the
equivalent fraction in symbols next to each diagram. The learners could therefore not only
listen to her and look at what she was doing, but could at the same time manipulate the
pieces they had been given (Figure 3).

Neither of the two teachers taught problem solving according to Polya. They gave their
learners steps, recipes or rules to follow in order to solve different kinds of mathematical
problems. When the learners struggled to solve the problems, which happened often, the
teachers always reminded them of the steps, recipes/procedures or rules that were taught
previously. For example, in Lesson 4, T3(E/NT) explained the four steps to problem solving
of multiplication with fractions by using the acronym of CMMS: change mixed numbers into
proper fractions, multiply numerators, multiply denominators and simplify (see Figure 4).
From the results, it can be concluded that T2(I/SP), who had two years of teaching experience but had undergone further training in special needs education, and T3(E/NT), who has 11 years of teaching experience but no further training in special needs education, used nearly the same number of teaching strategies effectively.

**POST OBSERVATION QUESTIONNARES**
The results here (for all four teachers) reveal that some teachers prefer some strategies like problem-solving, but due to time or other reasons they were unable to implement them. Most of them prefer scaffolding. Teachers gave statements as in Table 2.

<table>
<thead>
<tr>
<th>Table 2: Description of participants</th>
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<tbody>
<tr>
<td>T1(I/NT)</td>
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<tr>
<td>T2(I/ST)</td>
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<tr>
<td>T3(E/NT)</td>
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<tr>
<td>T4(E/ST)</td>
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**REFLECTIONS BASED ON THE RESULTS**
In order to respond to the question: Which teaching strategies are used by mathematics teachers for learners with learning difficulties in mathematics and their thoughts in facilitating learning? One can say that teachers tend to use scaffolding more than other strategies. It was interesting to see that teachers with special needs training used concrete objects when introducing lessons. T4(E/SP), with 53 years of teaching experience and special needs training, stood out from the rest of the teachers in using all teaching strategies, except for not teaching problem-solving strategies without guiding learners. This is in contrast to T1(I/NT), with one and half years of teaching experience and no special needs training, who did not make much use of the different teaching strategies. Teachers believe that certain strategies could be used, however they get restricted because of the type of learners they teach and the time constraints. They end up relying on explicit teaching and scaffolding and avoiding developing problem solving skills.

**CONCLUSIONS**
The findings of this study raise questions regarding formal special needs training. T2(I/SP), who had received formal special needs training, but had little teaching experience, compared well with T3(E/NT), who had more than ten years’ teaching experience, but no formal special needs training. T4(E/SP), with 53 years of teaching experience and special needs training, stood out from the rest of the teachers. The impact of formal special needs training on the use of the five strategies in class needs to be researched with a bigger sample for results that can be generalised, so as to make informed decisions about inclusive education.
From the results of this study it can be suggested that if inclusive education is to be a success, teachers should be equipped with the necessary special needs education training as it is internationally (Mbengwá, 2010), with the main focus on different instructional strategies. We argue that teacher trainers should focus on designing relevant training or qualifications for all teachers in South Africa as a way of preparing them to teach at inclusive schools. If all teachers study courses like remedial education and learner support at universities as part of their studies, they will be able to identify and help learners who have learning disabilities. As part of the training, we suggest that in addition to remedial education, UDL be introduced in Teacher Training courses in South Africa.

As discussed earlier, the South African government is shifting its focus to having inclusive schools (DoE, South Africa, 2001). Currently many learners in mainstream schools have intrinsic barriers to learning and mathematics teachers need to be able to adapt their teaching to accommodate these learners. Further research could examine the similarities and/or differences in the teaching strategies used by teachers who teach in special needs schools and those teaching in mainstream schools. Future research could focus on teaching problem-solving strategies as none of the teachers in this study taught problem-solving strategies without guiding learners. We align with Scherer, et al. (2016) as they argue that for inclusive education system for all, the focus should not be on trying to assist learners with mathematics learning disabilities, but rather focus on building a mathematics education system that no longer disables our mathematics students. In that way, teachers will be trained to teach all types of learners despite their abilities.

Both authors acknowledge that this paper is based on the Masters student work done by Elizma Louw.

REFERENCES


GRADE 6 TEACHERS’ BELIEFS ABOUT MATHEMATICS AS A SUBJECT

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ABSTRACT:
This paper reports on a qualitative study where beliefs held by four Grade 6 mathematics teachers about mathematics as a subject were investigated. Data collected after interviewing the teachers telephonically, revealed that mathematics is mainly seen as a practical subject, hence it must be taught practically and learners must do a lot of practice. Teachers also believe that concrete objects or manipulatives must be used when teaching mathematics since learners struggle with mathematics. Another category that emerged was beliefs that are policy-related. Teachers recommend that more time should be allocated for mathematics in order for teaching and learning to be effective. Teachers recommend a review of allocated time to teaching mathematics, allocation of teachers to schools using the PPM\(^1\), and change in pass requirements. Teachers also suggest that assistance should be sought from specialists for learners in their classes who have learning barriers.

Keywords: Teachers’ beliefs, teaching and learning, mathematics as a subject

INTRODUCTION, CONTEXT AND BACKGROUND OF THE STUDY

South African schools are divided into four phases, which are Foundation Phase: Grade R to Grade 3; Intermediate Phase: Grade 4 to Grade 6; Senior Phase: Grade 7 to Grade 9 and Further Education and Training Phase: Grade 10 to Grade 12. This paper focuses on Grade 6, which is the exit class (last grade in the phase) for the Intermediate Phase in primary schools. Exit classes are given a greater spotlight by the Department of Basic Education because learners in these classes are expected to demonstrate and apply acquired skills, knowledge and outcomes in all the grades they have passed, that is from Grade 4 to Grade 6 in the case of the intermediate phase. The spotlight is also seen in the fact that sub-districts concentrate more on the exit classes when conducting internal and external moderations.

Primary schools are institutions where learners should receive basic knowledge of all the subjects and not only mathematics. It is therefore essential that factors contributing to poor performance in mathematics be addressed even at a very early stage. Zakaria and Maat (2012) strongly assert that teacher beliefs are very critical in the implementation of teaching and learning. According to Smith (2014), the manner in which teachers are orientated towards a particular curriculum affects how that curriculum is used. This study was prompted by the fact that in overall learners perform poorly in mathematics (Venkat 2013), in spite of all the efforts put in place by the department of basic education. It is important to note that when learners perform poorly in mathematics in primary school, they are unlikely to choose mathematics in secondary school since they may perceive it as a difficult subject.

THE RESEARCH QUESTION AND THE CONCEPTUAL FRAMEWORK

In order to investigate the beliefs that mathematics teachers in Grade 6 hold, the research question for this study was established as follows: What are the beliefs that Grade 6 mathematics teachers have about mathematics as a subject?

A conceptual framework which served as a reference for this study was established using teacher beliefs from Handal (2003), in conjunction with those from Beswick (2008), see Table 1 below. These beliefs were used as reference to interviews held with teachers, to

\[^1\text{PPM (Post Provisioning Model) — model or policy for determining number of teachers to be allocated to schools.}\]
investigate if teachers hold these beliefs or they hold other beliefs in addition to these, or they hold other beliefs that were not mentioned in literature consulted.

Table 1: Teacher beliefs from Handal (2003) and Beswick (2008)

<table>
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<td>Mathematics is a complete static body of knowledge with logic and structure. Mathematics is a collection of facts, rules, algorithms and skills to be mastered for utilitarian purpose. Mathematics is a discipline based on rules and procedures to be memorized.</td>
<td>All learners can acquire mathematical skills necessary for life in the modern society. Mathematics requires a good memory. Mathematics requires logic and not intuition. Some people have a mathematical mind and others do not. Mathematicians do problems quickly in their heads.</td>
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LITERATURE REVIEW

Several authors such as Liljedahl (2007), White, Way, Perry and Southwell (2006), Kalckman (2011), Handal (2003) and Adam (2012) indicate that teachers’ beliefs do not emanate from their teaching practice, but originate from their past learning experiences whilst still at school or tertiary institutions. This indicates that teacher beliefs of mathematics and the teaching of mathematics come a long way and might have deeply rooted structured systems which may have dire impact on the teaching and learning of mathematics. However, teachers may begin to develop beliefs about the learners doing mathematics after entering the teaching profession. Experienced teachers may have strong beliefs in this regard based on the number of years they spent in teaching and the different kinds of learners they have taught.

In addressing the main research question of this study, we established secondary questions along with Polly, McGee, Wang, Lambert, Pugalee and Johnson (2013), Handal (2003) and Adam (2012). They identified three categories in which beliefs can be divided, namely;
1. The teachers’ beliefs about mathematics as a subject
2. The teachers’ ideas about the nature of mathematics teaching and
3. The teachers’ ideas about the learning of mathematics

These categories of beliefs are crucial in understanding the types of beliefs held by mathematics teachers. If teachers do not agree that all learners are able to acquire mathematical skills necessary for life, they will always argue that not all learners can pass mathematics and many reasons will be presented for their argument.

METHODOLOGY

The study was conducted in primary schools, of the North West Province. Qualitative data collection methods were used in which four Grade 6 teachers were selected from the four primary schools. Convenience sampling was used, so as to minimise the cost of travelling by sampling participants in the vicinity of the researcher. Telephonic interviews were conducted after hours at the time agreed upon with the teachers and transcribed. All teachers sampled were qualified and had sufficient teaching experience. Qualitative research was used in this study because it is a field of study which is interpretive and takes a naturalistic approach, which includes many methods such as interviews and classroom observations (Dennis, Carspecken & Carspecken 2013). Qualitative research was important in this study because in qualitative research, data collection methods such as interviews enables the researcher to see and hear the participants’ actions at first hand.

DATA OBTAINED FROM INTERVIEWS

There were four teachers who were sampled. All teachers were asked the same (three) questions for interviews.
Responses of participants to interview Question 1:
Q1: What are the beliefs that you have about mathematics, the teaching of mathematics or the learners that you teach mathematics?

P1: Ja, …Firstly, mathematics is a practical subject. The learners must practice. And then teachers should use manipulatives when they teach…er, previously we did not have teaching aids and it was difficult to teach mathematics, that is why we resorted to textbook method. But now with the introduction of mathematics laboratories in schools it is much better…er, the other thing is that the classroom must be print-rich. But now the problem with our learners is that there is no initiative on the side of learners. They cannot study on their own, the teacher must always be there you see.

P2: Er, firstly is that mathematics is difficult for most of the learners. …most of them are not serious with their work. When the teacher is not in class they make a lot of noise and they just sit and do nothing… they must learn to practice on their own because the teacher cannot always be in class, sometimes you go to workshops or attend meetings.

P3: Ja, the beliefs in mathematics are that in South Africa, er, we take mathematics as a difficult subject, but it is not that difficult, you see, it is just that people don't get clear light into it, or you will find that the teacher is overloaded with many subjects. To me if I was the minister, I would say teachers who teach mathematics let them teach mathematics only

P4: let me start by saying mathematics needs people who can think quickly, not people who cannot work with numbers. And this must start at home, At school the teacher can bring along real objects so learners can see what they are being taught about. This will make them understand better when they see and touch objects.

RESPONSES OF PARTICIPANTS TO INTERVIEW QUESTION 2
Q2: How do the beliefs that you mentioned affect your teaching?

P1: mmm.. as a teacher when learners do not understand; they challenge me to come up with different teaching strategies to improve my teaching. But now in primary schools it is unfortunate that all learners must do mathematics and they are all expected to pass irrespective of their differences. When learners do not pass the average pass percentage becomes very low and it affects me as a teacher.

P2: Mmm… when I teach I always repeat the topic with learners and after doing that some learners still do not understand. This makes me hopeless because when I repeat I think they will improve…

P3: Er, these beliefs affect me because with the management duties that I have, I do not manage. As the school manager with 53 periods that I must teach, it is difficult to cover the syllabus. On top of that I have to attend management meetings time and again so I don’t see learners more often.

P4: Er… they affect me it means that learners understand better when they see and touch objects … and they will not forget easily. Teaching aids or real objects must be used in class.

RESPONSES OF PARTICIPANTS TO INTERVIEW QUESTION 3
Q3: What is it that you recommend to improve your teaching and learner performance?
**P1:** Firstly, I recommend that mathematics laboratories be established in all the schools because they are very helpful in keeping learners’ interest. Secondly, extra effort is required from learners, if parents can help them at home with their homework, because most of them just come to school with their homework not done. If parents can be informed in parents’ meetings to help learners at home I think it would be better.

**P2:** You see, the problem is the PPM, it must change because they are looking at the number of learners in the class but then the teacher teaches many subjects including mathematics as well. The other thing is number of years in the phase. Pass requirements must also change. And also time, they must allocate more periods for mathematics because maths is a difficult subject.

**P3:** I recommend study groups for learners. If learners can do study groups it will be better because there is no time to treat all these topics. They are suffering because of the PPM. They should at least give us temporary teachers to offload the staff.

**P4:** For teachers I recommend that they must start from simple to complex when teaching and use teaching aids. The department of education must hire assistant teachers permanently to help learners with homework just like in Gauteng Province, because some parents do not understand the homework. The department must also hire specialists, occupational therapists and psychologists who can help learners with barriers because teachers do not have time to do intervention.

**DISCUSSION OF THE FINDINGS**

Some participants had similar beliefs. It has been found that teachers hold beliefs that can be classified into four categories, of which the first three categories were used by Handal (2003). The first category is beliefs about mathematics as a subject. Beliefs falling in this category were for an example: mathematics is a practical subject; mathematics is a difficult subject for learners and teachers. The second category is belief about the teaching of mathematics. Beliefs in this category were teaching aids or manipulatives should be used, classroom should be print-rich, different teaching strategies should be used and teachers should move from simple to difficult when teaching. The third category is beliefs about learners who do mathematics. Beliefs in this category are: learners should be able to think quickly and be able to work with numbers.

These beliefs have the same meaning with the belief from Beswick (2008) that says mathematicians do problems quickly in their heads. However, teachers’ belief that learners should be able to work with numbers is in contradiction to Beswick (2008) when he says that all learners can acquire mathematical skills necessary for life. According to teachers’ belief, some learners cannot work with numbers or find it difficult to do so. This supports Beswick (2008) again when he says that some people have a mathematical mind while others do not.

It was important to note that there is a new category that emerged based on the beliefs of teachers that could not be classified in either of the first three categories. This new category is beliefs that are policy-related, where teachers believed that PPM should be reviewed, more time is required to teach mathematics, pass requirements should change, and mathematics teachers should teach mathematics only (because they feel that they are being overloaded with work). Teachers also brought the issue of being unable to cover the prescribed content due to overload, especially in small schools. This leaves learners unprepared to face the challenges of the grade they are progressing to. They also believe that some learners have learning barriers hence require intervention from psychologists since they believe they are not in a position to teach such learners; despite teaching strategies they use. Recommendations that require policy change, can only be done if the Department of Basic Education consult with all stakeholders before effecting such changes.
This may take a long time to be implemented, because of their financial implications or resistance from the system or the stakeholders. It was also revealed that teaching learners with barriers to learning seems to be frustrating to some teachers. This is demonstrated in the fact that Participant 2 used repetition to learners who did not understand. When repetition did not work, she became hopeless.

The research question of our study: **What are the beliefs that Grade 6 mathematics teachers have about mathematics as a subject?** Was answered below.

Teachers’ beliefs identified from the interview transcripts can be classified according to the categories identified by Polly et al. (2013), Handal (2003) and Adam (2012).

**BELIEFS ABOUT MATHEMATICS**

Two teachers believe that mathematics is a practical subject. One of the teachers believe that mathematics is a difficult subject, it requires learners who can work quickly with numbers and to also have a mathematical mind. Saying mathematics is a difficult subject can be discouraging to those who want to study it further, without them being able to discover for themselves the challenges that they can come across, and it is against Beswick (2008) that all learners can acquire mathematical skills necessary for life. We believe that any subject has its own challenges, and it is incumbent of the subject teacher to use innovative approaches that will enhance understanding and foster learners’ interest. We believe that there are mathematical and non-mathematical minds. The mind can be receptive once interest in the subject is established. So all learners can have a mathematical mind if teachers use mathematical games and strategies that will help capture learners’ interest throughout the lesson.

**BELIEFS ABOUT MATHEMATICS TEACHING AND LEARNING**

Two of the teachers believe that in order to teach mathematics effectively, teachers should use teaching aids or concrete objects to enhance understanding of concepts. They also recommend that classrooms should be print-rich to encourage unconscious learning. In this category, three teachers recommend that learners should work in groups so that they can be able to engage in discussions to help one another.

**BELIEFS ABOUT THE LEARNERS DOING MATHEMATICS.**

Three teachers feel that learners are not serious with their work, because most of the time they do not complete their work. As a result, this will cause poor performance. Teachers also recommend that learners should practice a lot if they want to do well in mathematics, because mathematics is a collection of facts, rules and skills to be mastered, and requires a good memory (Beswick 2008). In addition to the categories identified by Handal (2003), the researcher discovered the fourth new category which was not mentioned in literature consulted namely, beliefs that are policy related.

**BELIEFS THAT ARE POLICY-RELATED**

Teachers feel that they are overloaded with work especially the small schools, and on top of that they are required to do intervention for learners who do not perform well and have learning barriers. As a result, they recommend that the PPM should be revised, pass requirements should change and help should be sought from specialists such as therapists and psychologists to work only with those learners with barriers to learning. Teachers also feel that homework assistants should be hired since most parents are unable to assist learners at home.

**CONCLUSIONS AND RECOMMENDATIONS**

From the results of our study, it was revealed that teachers’ beliefs are divided into four categories of which three of them are mentioned by Handal (2003). However, teachers do not share the same beliefs as Handal (2003). Nevertheless, teachers share some beliefs that are mentioned by Beswick (2008), namely: mathematics require people who can work with numbers and mathematicians do mathematical problems quickly in their minds. Most beliefs that teachers hold were neither mentioned by Handal (2003) nor Beswick (2008).
Teachers regard mathematics as a practical subject, hence it must be taught practically. In that case learners must do a lot of practice, which might not all be possible based on the amount of time allocated in class from the PPM. PPM is part of policy-related category that emerged. The teachers believe that the time allocated to the teaching of mathematics is not sufficient and must be reviewed. Teachers believe that more time must be allocated for mathematics teaching to be effective. In that way, learners will have more time to practice in class. Teachers believe that small schools should be given special treatment, which includes regular visits by the sub-district officials.

Our believe is that since beliefs are regarded as strong determinants of teachers’ behaviour in classrooms (Barge 2013), it is important that teachers’ beliefs be investigated in order to understand the reasons behind their instructional practices, because ultimately, teachers’ instructional practices influence learner achievement. The focus of this study was only to unveil beliefs that mathematics teachers have. The effect these beliefs have on the performance of learners may be investigated in further studies. The research may also explore the influence of teachers’ beliefs on their instructional practices.

Both authors acknowledge that this paper is based on the Masters student work done by Rosina Nkadi Ngoako.

REFERENCES
ABSTRACT – Mathematics education research argues that mathematical problem solving relies heavily on visualisation in its different forms and at different levels, far beyond the obvious field of geometry. Mathematics educators are thus encouraged and inspired to ‘see’ not only what comes ‘within sight’ but also what we are unable to see when reviewing their students’ work. The qualitative case study described in this paper speaks to this research as it examines the use of visualisation processes (as called visual imagery) in word problem solving. In our study, 17 Grade 11 learners participated in one-on-one task-based interviews. They answered 10 word problems, which we compiled in a worksheet, whose aim was to analyse the evidence of visual imagery in the participants’ solutions and problem solving strategies. To analyse this evidence, we developed a visual imagery analytical framework that facilitated the analysis of the participants’ responses in the worksheet, their interview transcripts as well as gestures in video-recordings. The findings suggest that developing tasks that encouraged the use of visual imagery to solve mathematical problems help learners to improve their problem solving functionality. Thus, all the 17 participants managed to use some kind of visual imagery during task-based interviews, although at different levels and in many different ways.

Keywords: Problem solving; Word problems; Visualisation

INTRODUCTION

The study presented in this paper observed how selected Grade 11 learners were encouraged through task-based interviews to incorporate visualisation in their word problem solving. Although much neglected in actual classroom practices, the significance of visualisation as a strategic problem solving method in mathematics has attracted interest from mathematics education researchers over the years (Arcavi, 2003; Csíkos, Szitányi, & Kelemen, 2012; Rivera, 2014). Arcavi (2003, pp. 216–217) claims that as a human and cultural creation dealing with objects and entities different from physical phenomena, mathematics relies heavily on visualisation in its different forms and at different levels far beyond the obvious field of geometry and spatial visualisation. Further, Edens and Potter (2007) claim that “visualising objects and graphically representing numerical information are important mathematical tools that help students to solve problems and to understand [mathematical] concepts” (p. 285). Similarly, Csíkos, Szitányi, and Kelemen (2012) note that because “mathematical concepts and relations are often based on visual mental representations attached to verbal information, the ability to generate, retain and manipulate abstract images is obviously important in mathematical problem solving” (pp. 49–50). Visual strategies are thus necessary for mediating understanding of mathematical objects among problem solvers (Rivera, 2014). Hence, placing visualisation at the service of problem solving “may play a central role to inspire a whole solution, beyond the merely procedural” (Arcavi, 2003, p. 224).

This paper explores 1) the types of visual imagery evident in the learners’ solutions to word problems and 2) an environment (i.e. types of tasks and classroom culture) that supports the use of visual methods and facilitates an improvement in problem solving performance. These objectives stem from a bigger visualisation study (Dongwi, 2018), which has shown how the participants’ use of visual methods made word problems easier to solve. We ask the following question: What is the role of visual imagery in word problem solving of the selected learners?

VISUAL IMAGERY

When Presmeg (1986) defined a visual image as “a mental scheme depicting visual or spatial information” (p. 42), she claimed to have deliberately broadened the definition to ensure inclusion of all other kind imagery, which depict shape, pattern or form without conforming to the "picture in the mind" notion of imagery (Clements, 1982). This also included imagery which reflected the vividness and clarity of a picture (Presmeg, 1986). Visual imagery refers to the ability to formulate mental representations of the appearance of
objects and to manipulate these representations in the mind (Hegarty & Kozhevnikov, 1999). To define and analyse visual imagery in our study, we adapted Presmeg’s (1986) five categories of visual imagery. Presmeg (2014) acknowledges a considerable growth in research “on how visualisation is implicated in the teaching and learning of mathematics at all levels” (p. 151). She however noted that many of the questions that emanated from her early 1980s research were still unanswered and in need of investigation (Presmeg, 2014). It is against this background that we adapted her visual imagery framework, which we defined as follows:

**Concrete pictorial imagery (CPI)** – this refers to the concrete image(s) of an actual situation formulated in a person’s mind – i.e., a picture in the mind, drawn on paper or described verbally.

**Pattern imagery (PI)** – this refers to the type of imagery in which concrete details are disregarded and pure relationships are depicted in a visual-spatial scheme.

**Memory imagery (MI)** – this refers to the ability to visualise an image that one has seen somewhere before. This too includes a history of recurrent occurrences.

**Kinaesthetic imagery (KI)** – this is the kind of imagery that involves muscular activity. A kinaesthetic visualiser wants to feel and touch.

**Dynamic Imagery (DI)** – this imagery involves processes of transforming shapes i.e. redrawing given or initially own-drawn figures with the aim of solving a problem.

**METHODS AND PROCEDURES**

All the participants in our study completed the Enacted Visualisation Geometric Reasoning Tasks Worksheet (EVGRT) as part of data collection. The EVGRT was a set of ten mathematical problems that we compiled into a worksheet that was administered to the selected learners during semi-structured one-on-one task-based interviews. Interviews were audio- and video recorded and responses, both verbal and nonverbal were transcribed. The interviews consisted of the EVGRT worksheet that individual participants completed in the presence of the first author of this paper.

What sets these tasks apart from ordinary daily mathematical problems was their unusual and interesting nature. They required some sort of visual imagery to solve, and inspired numerous possible solution strategies. The format of each task provoked the learners to discover their own methods and visual representations that also necessitated some sort of mathematical reasoning. In the bigger PhD study (Dongwi, 2018), we developed 10 items for the EVGRT worksheet with the appropriate rationale for each item. In this paper however, we only chose two out of those 10 tasks and discuss how three out of our 17 participants solved them. We opted for two tasks and three participants given the paper’s space constraints.

**FINDINGS**

The data analysed for this paper presents and describes how each of the three selected participants used visual imagery to solve two EVGRT viz. the rectangle task and the dice (cube) task. These tasks were developed to encourage the participants to represent word problems visually when solving them. The nature of the tasks also created rich opportunities for the participants to articulate and reason their way through problem-solving process. We placed in parentheses the codes of the visual imagery framework (e.g. CPI, PI, MI, KI and DI) to show how the participants incorporated visual imagery in problem solving. A more detailed framework with observable indicators is in the bigger PhD study (Dongwi, 2018). Below is a synopsis of how each participant visually represented each of the given tasks in problem solving.
THE RECTANGLE TASK – WORD PROBLEM WITHOUT PICTORIAL REPRESENTATION

The longest side of a rectangle has a length of 63 cm and the diagonals have a length of 65 cm each. Find the width of the rectangle (in cm).

Jordan’s problem solving strategy of the rectangle task

Jordan paused when he read ‘the diagonals’. He claimed to have imagined drawing a triangle (CPI) during his long pause but he nevertheless sketched a rectangle (Figure 1a) that he later divided into triangles using the diagonals as sides for the triangles (DI). He marked with a question mark the width of the rectangle that he had to find.

![Figure 1: Jordan’s visual representation of the rectangle task](image)

Jordan extracted the first triangle (DI) (Figure 1b) from the complex rectangle (Figure 1a) to supposedly find side CB but then realised that he did not have sufficient information ("wait, it is going to be \(AB^2 + AC^2 = BC^2\)" (PI)). He also realised that the triangle was isosceles, which meant that he could not use the Pythagoras’ theorem, so he revisited his original sketch. He quietly and thoughtfully traced triangles with his finger (KI) and then extracted the second triangle (DI) (Figure 1c) which he also realised that it could not generate the needed solution. With his head between his hands, he looked puzzled while staring at the sketched rectangle (CPI). He gestured lifting up each of the extracted triangles and placing it on top of its corresponding triangle in Figure 1 (a) (KI). He paused and then exclaimed, “Ooh…now I see!” (CPI). He noticed and extracted a right-angled triangle (DI), ABC (Figure 1d). He placed a question mark on the unknown side CB, and used the Pythagoras theorem to find the final answer (Figure 1e).

Ellena’s problem solving strategy of the rectangle task

Slightly different from Jordan’s method, Ellena solved the task in four steps. She straightaway sketched a rectangle after she read the problem for the first time and then the diagonal when she read it for the second time (CPI) (Figure 2a). She extracted a triangle in Figure 2(b) in an attempt to find the width of the rectangle (DI). When she realised that this triangle could not generated what she wanted she wondered whether she had done anything wrong. She claimed to have been confused and could not figure out how she could find the width of the rectangle although she knew the lengths and the diagonals; she believed that she encountered a dead-end. This was partly because she did not yet at that stage notice the two right-angled triangles within the sketched rectangle (Figure 2a). Task-based interviews are helpful for such moments. The purpose of task-based interviews in our study was to prompt the participants to use visual imagery in problem solving. They were also encouraged to use both verbal and nonverbal modes to communicate their problem solving strategies (Dongwi, 2018). Cohen, Manion, and Morrison (2011) state that semi-structured interviews in particular enable researchers to motive their participants to discuss their thoughts, feelings and experiences. Hence, when Ellena was probed to unpack her complex rectangle in Figure 2(a), she identified different types of triangles that could be extracted from it (DI). She consequently extracted Figure 2(c) and worked out her solution (Figure 2d) (PI, DI).
Millie’s problem solving strategy of the rectangle task

Millie claimed to have formulated mind pictures while reading the task (CPI). She took a long pause and then commented: “I’m just going to draw it”. When asked what she was going to draw, she sketched a rectangle with a diagonal that she claimed represented her mental image (CPI) (Figure 3a). She worked privately on a calculator and then produced the solution in Figure 3 (b) (PI, CPI).

THE DICE (CUBE) TASK – WORD PROBLEM WITH AN ABSTRACT DIAGRAM

On a dice, the numbers on opposite faces add up to 7. The dice in the diagram is rolled edge over edge along the path until it rests on the square labelled X. What is the number on top in that position?

By its nature, this task inspired the participants to use a combination of the 5VIs, ranging from moving pictures in the mind to actual dice rolling. The participants used hand gestures in this task more than they did in any other task in the worksheet. Below are summaries of how the three participants solved the dice task.

Jordan’s problem solving strategy of the dice (cube) task

Jordan related the dice in the given diagram to a cube when he visualised the opposite sides of the dice (MI): “so if it is a cube, this side and this side will add up to 7, each one of the opposite faces” (Figure 4a) (KI). He silently used hand gestures as he proceeds through problem solving (CPI, KI). Asked to reveal what was in his mind he explained as follows:

See now this one is two [circles the top of a dice with a pencil and writes 2 as he speaks (Figure 4c (KI)) and the opposite will be 4…no… sorry 5 is equal to 7… we are looking for what will be the number when it fell on x [circles the x]. So it’s gonna be 3 plus 4 is equal to 7, 1 plus 6 equals… When it’s lying like that [uses his hands to demonstrate the movement (KI) (Figure 4b)], it will lie on 3 [writes 3, 2 and 6 on the square path to indicate the number that will land on each square as the dice is rolled (Figure 4c)]. …the opposite number will be 4, so when it move to the side, 3, 2 [uses a pencil to visualise a rolling dice (KI, DI)], 6 and 1 then it will be… Okay [holds his arms and rolling his head as if though moving a dice from one square to the next (CPI, KI, DI)] here we have 3; x equals to 3.
Jordan visually demonstrated the actual rolling of the given dice by incorporating various 5Vis. Although he initially thought $x = 3$ was the solution to question, he later rectified it as he concluded that 3 was the number on top when 4 landed on square $X$.

**Ellena’s problem solving strategy of the dice (cube) task**

For this task, Ellena did not make any calculations or any drawings. She only used mind pictures combined with hand gestures for her problem-solving strategy.

In Figure 5 (a), Ellena’s left hand represents the position (orientation) of the dice while her right hand shows the direction of the next move (CPI, KI, DI). She uttered, “This one goes here” (Figure 5b) before she became silent and used gestures in Figures 5(c) through 5(e) (CPI, KI, DI). The sequence of her movement through these figures was top-side-bottom (PI). After a few cycles of hand gestures and whispers, she requested for ‘that box’ (a designed box in a form of a cube that she had used in an earlier task) (MI, CPI). She calibrated it with numbers from 1 to 6, depicting the numbers on the faces of a dice that she literally rolled next to the given diagram (KI). She pronounced three as the answer to the question. Unlike Jordan and Millie there was no confusion whatsoever in Ellena’s problem solving strategy for this task. She constantly reminded herself of what the main question was and she kept on repeating it (CPI) “what is the number on top in that position?” Hence, as she rolled the dice both in her mind and on paper (KI, DI), she always knew what she needed to find.

**Millie’s problem solving strategy of the dice (cube) task**

When she turned to the task and before she read anything, Millie related to how she enjoyed working with diagrams and how such as the given one fascinated her (MI). She articulated shapes of the dice in each square even before she familiarised herself with the question (CPI). She even claimed to have visualised a rolling dice in her mind when she finally decided to read the question (CPI, DI). She demonstrated the movement of the dice by using her fingers and a pencil (KI, DI) (Figure 6a).

She paused a few times whenever she reached the third square with her imaginary rolling dice (CPI, KI, DI). She would then repeat the whole rolling process all over again (CPI, KI,
She admitted to have gotten a little confused by the dynamic pictures in her mind (DI). She sketched a net of the dice (CPI) (Figure 6b), turned the whole worksheet around to ensure a true representation of the given diagram (KI, DI). She worked from the net to sketch a dice on the third square (CPI, DI) (Figure 6c). Using the two sketches, she gestured with her fingers as she again visually moved her dice this time through the third square (KI, DI). These series of visual imageries enabled Millie to determine the number on square X and hence, to answer the question. She rolled an eraser in the square path to affirm the accuracy of her solution (KI, DI).

**CONCLUSION**

Visualisation processes used by the learners during problem-solving activities in our study proved both helpful and strategic. The participants used visual imagery in their minds, through gestures and when sketched on paper. When they solved the rectangle task, Jordan used trial and error sketching to determine the correct sketch that eventually helped him to solve the task. He mostly incorporated CPU, KI and DI through sketches and gestures during this task. Like Jordan, Ellena also used various sketches before she could determine the sketch that generated the correct method and solution to the rectangle task. When she somehow got confused, she employed dynamic imagery that enabled her to extract the necessary triangle that led her to solve the problem successfully. Unlike the other two participants, Millie’s use of visual imagery to solve the rectangle task centred on concrete pictorial imagery. When she read the problem, she first internalised it and organised it in her mind before she uttered or sketched anything. This enabled her to conceptualise her thinking and effortlessly find the solution to the problem in relatively fewer steps in comparison to Jordan and Ellena. For the dice task, Jordan mostly used gestures with little writing on paper. Ellena only used gestures and Millie incorporated both gestures and sketches. All participants claimed to have experienced moving pictures in their minds when they imagined a rolling dice along the given path. They were able to see beyond only what came to mind. Their use of visual imagery in word problem solving offered them what Arcavi (2003) calls “a method of seeing the unseen” (p. 216), especially when they closed their eyes to see the numbers on the opposite faces of the dice while they imaginatively rolled it.

Lastly, from our observation, we have enough evidence to conclude that the use of visual imagery to solve word problems in our study facilitated the participants’ problem-solving strategies and influenced their reasoning. Further, using diagrams helped the participants to see the hidden message in the linguistic information, which enabled them to better interpret and understand the questions. Van Garderen, Scheuermann and Poch, (2014) accentuate the complexity in the ability to use a diagram as a tool for solving word problems and warn that it should not be underestimated. Encoding information from a mathematical problem into a diagram requires an extensive knowledge base as it involves decoding the linguistic information and encoding it into visual information. This includes “knowledge related to the ability to select, produce and productively use a diagram as a problem-solving tool as well as the ability to critique and modify or generate a new diagram where needed within the context of a problem-solving situation” (p. 136).

**REFERENCES**


THE PRACTICALITY OF TEACHING MATHEMATICS IN SHONA IN THE ZIMBABWEAN PRIMARY SCHOOLS
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ABSTRACT – This study aims to explore the feasibility of teaching mathematics in Shona in Zimbabwean primary schools. The teaching of mathematics in indigenous languages as early as the infant stage in Zimbabwe was justified by the Ministry of Education based on the understanding that pupils are capable of expressing mathematical ideas freely if their native language is used for instruction. However, in Zimbabwe, despite Shona being one of the local languages spoken by most learners, the decision has provoked disagreements and contentions among educators. It is in this regard that the possibility of teaching mathematics in Shona is investigated. The study is informed by the qualitative approach of research, through interviews and observations to capture the concerns and perceptions of primary school teachers about the issue under discussion. The study found that there is a mismatch between the ministry’s expectations, the teaching context and the recognition that Shona is receiving in the education system of Zimbabwe. The study recommends that appropriate materials be availed to support the use of Shona to teach mathematics at infant level, practitioners receive appropriate training to implement the curriculum and that Shona should be adequately recognised in all sectors of the country.

Keywords: Curriculum, mathematics, Shona, English, primary schools, language

INTRODUCTION AND BACKGROUND
The purpose of this study is to explore the practicality, significance and contribution of teaching mathematics in Shona to the development of mathematical knowledge of infants in Zimbabwean primary schools. The study of teaching Mathematics in indigenous languages has emerged to be favourite for analysis by most researchers in Zimbabwe because the concern of which language to use for teaching and learning is indeed a crucial one in multilingual contexts (Jegede, 2011). According to Lee (2006), pupils may think that they do not know a certain concept in mathematics, when what they cannot do is to express the idea in a certain language. The ministry of Education in Zimbabwe therefore introduced the teaching of mathematics in indigenous languages on the basis that pupils can express mathematical ideas better and freely if their local language is used for instruction. Studies by UNESCO (2003) pointed out that instruction in the first language is beneficial to success in other subject areas including mathematics. Chivhanga (2014) also concurred that children who begin their education in local language, make a better start, have confidence and will continue to perform better. This implies that the first approaches that a learner makes towards mathematics learning are important for future learning. The ideas alluded to above show that if Shona is used to introduce concepts as early as the infant stage, children become capable of making well-informed decisions, which is likely to curtail the learners’ academic impairment in future. Hence, Chivhanga (2014) asserted that mother tongue (Shona) should be promoted to enhance concept formation among learners who grapple with the acquired language (English).

In contrast however, despite Shona being one of the local languages popular among learners, the decision to enforce the teaching of mathematics in Shona by the Ministry induced contentions among educators (Maponga 2017- Herald reporter). Hence, most Zimbabweans, according to Chivhanga (2014) prefer English language as the medium of instruction in education. Some scholars such as Moschkovich (2012) also argue that instruction in mathematics should pay attention to enhancing mathematical reasoning and not accuracy in using a language, suggesting that language has limited contribution in the acquisition of mathematical knowledge. Mathematics is a specialised second language and should therefore be presented to the students in second language (Jones, et al., 2008). Like any other language, mathematics has its own didactics and symbols peculiar to mathematics. Studies by Jegede (2011) have shown that learners fail mathematics due to specialised concepts such as “quotient, divisor, denominator, standard deviation, to mention
a few, which may not be well explained either in first or second language. To support this, Kan and Bulut (2015) assert that mathematics has concepts that are beyond the capabilities of native languages. This may suggest that attempting to interpret and transcribe mathematical concepts in Shona is likely to distort the real meaning of the ideas being taught. The debate around this topic left most Zimbabweans asking themselves; “Can mathematics be taught in local languages?” It is against this background that the possibility of teaching mathematics in Shona in the primary schools of Zimbabwe is investigated. The study was guided by the following research questions: 1. What are the teachers’ perceptions about teaching mathematics in Shona in the Zimbabwean primary schools? 2. How feasible is it to teach mathematics using Shona as a medium of instruction in the Zimbabwean primary schools?

CONCEPTUAL FRAMEWORK

This study is premised on the view that the acquisition and development of children’s mathematical knowledge in the early stages of learning is based on the language used as the medium of instruction (Edmonds-Wathen et al., 2016). To support this idea, Vukovic and Lesaux (2013) aver that language ability is essential for children’s mathematical development and that learners’ mathematical difficulties may reflect deficient linguistic process. Warren, Cooper and Baturo’s (2004) study also revealed that many indigenous learners have difficulties when learning mathematics and that the language background of these learners can impact significantly on all educational outcomes. Hence, Vukovic and Lesaux (2013) aver that the abstract symbols inherent in mathematics can be conceptualised by learners through language proficiency. This implies that it is through the language used for instruction that mathematical ideas are conceptualised. Dutro and Moran (2003) narrate the metaphor of bricks and mortar to explain the connection between mathematics content at infant level and the language used to communicate it. The bricks represent the mathematics content such as symbols, shapes, etc and the mortar represents the ordinary language that connects or joins the content symbols in order for the (symbols) to make sense to the learners. This means without proper mortar (language), mathematical concepts remain cluttered and unconnected in the minds of the children. The study hence, seeks to explore the possibility of teaching mathematics in Shona in the Zimbabwean primary classrooms.

LITERATURE REVIEW:

Language Perceptions in Mathematics Teaching

UNESCO (1953, p. 8) posit, “one can admit that the best vehicle of teaching is the mother tongue of the child.” However, even though Shona is the language spoken by most learners in primary schools in Zimbabwe, the language has not assumed much significant role in the classroom (Chivhanga, 2014). According to Chivhanga, Zimbabwe adopted a language policy from its colonisers which marginalised the use of indigenous languages. As a result, English language has remained a prestige-laden language, held at high esteem. It has also been considered as the most appropriate language to be used for instruction in all the subjects learnt in primary schools, including mathematics. Howard and Perry (2019) argue that the notion of poor performance can sometimes be devastating, especially if the accepted views of success held by one group, reinforce failure in another. This idea may suggest that failure to understand some mathematical concepts because of language deficiencies of one group imposes an unfair advantage on the learners who learn the subject in the first language. According to Kyeyune (2003, p. 173), “the effectiveness of teaching or learning at any level depends on the effectiveness of communication between the teacher and the learner.” This suggests that mathematics may be effectively taught if it is packaged in an appropriate language. To support this, Salami (2008) also asserts that the language of instruction enhances or impedes the quality of education. Jegede (2011) hence, proposes that the language used for instruction can be a problem if the concepts taught are not in the learner’s home language. This means mother tongue helps develop children’s abilities in school and provides greater understanding of what they learn. However, Jegede (2011)
recommends that mathematical concepts can be learnt effectively if English language is supplemented with the learners’ home language (code-switching). Scholars like Edmonds-Wathen (2015) and Warren et al. (2004) have also written much about the benefits of using indigenous languages to teach mathematics at early stages of schooling. The topic has been prevalent among researchers but one would wonder whether this is feasible in reality or has just remained as an intended goal of this idea. The major question however, is; can Shona be effectively used as a medium of instruction in mathematics lessons in Zimbabwe? The study therefore seeks to contribute to a repertoire of mathematics knowledge by suggesting ways to improve and develop infants’ mathematical knowledge through a language at the early stages of learning.

METHOD
Sample & Research Procedures
The study is informed by the qualitative approach of research exclusively, which incorporates observations and focus group interviews with primary school teachers in Zimbabwe. Purposive sampling where the researcher made a conscious decision regarding the school teachers that would provide the desired information, was used. The study targeted infant teachers (Grade 1 to 3) in government urban and rural schools. Four primary schools in Harare (2 from low density areas (LDA) and another 2 from high density areas (HDA)) and 1 school in the rural areas of Mashonaland Central province were considered for the research interviews and observations. Participants at each school formed one focus group for teacher interviews. With the ethical approval from the Ministry of primary and secondary education in Zimbabwe, a total of 13 teachers from three districts were interview. The interviews were used to depict the teachers’ perceptions, anticipations, feelings, experiences and the ways in which they make sense of the process of teaching mathematics using Shona as a medium of instruction. Subsequent to the interviews, 5 teachers from those that were interviewed, were observed teaching mathematics in order to understand and depict the successes, benefits and/or challenges of teaching and learning mathematics in a particular language. Data from interviews and lesson observations were audio recorded and transcribed. Field notes were also written from interviews and lesson conversations. The features, impact and the implications of the language used in teaching mathematics were discussed. All names used in this paper are pseudonyms.

RESULTS AND DISCUSSIONS
Teachers’ perceptions and Use of Indigenous Languages
This study found that the language used for mathematics instruction was varied across the schools as determined by the school locations. Data collected from the interviews and lesson observations revealed that the way most teachers conducted themselves, in terms of language use in teaching mathematics in the high density, rural and low density areas was disparate. This implies that the teachers’ decisions regarding the language to use when teaching mathematics in the primary schools were informed by the learners’ prior learning and by the dynamic nature of language in the pupils’ classrooms. Hence, the Queensland Indigenous Education Consultative Body (QIECB), (2003) asserted that the background of the learner has a pivotal impact in determining the language to be used in the classroom as well as educational outcomes.

When teachers were asked to state and give reasons for use of a particular language, most teachers in the low density area (LDA) schools indicated that they would prefer English language. They explained that they only use Shona in the case where children have difficulties understanding a concept. However, they argued that pupils in their areas did not have problems with English language and that the learners actually liked the language. In addition, the schools also encouraged the use of English language in the classrooms. The following remarks illustrate one of the grade 2 teachers, Lilian’s views on this issue.
"I teach in English. I only introduce Shona phrases where pupils have problems. ....Yes, the pupils do understand English because they start learning English from ECD, especially from this community. Our catchment area is an English speaking community. When I give a test like this one here (showing the test) it is in English and they are supposed to read it as it is. So I teach them in English so that they are able to read it....parents are flocking to this school, (looking for places) because children are taught in English, and the school is proud about it."

Vee, a grade two teacher from another school, concurred.

"I prefer English language. I use Shona when necessary. The pupils show interest in English language. English is also encouraged by the school. Parents have a negative attitude towards Shona. They want their children to be taught in English."

Lilian’s speech suggests that English speaking schools are associated with high quality learning. Both Vee and Lilian raised sensitive issues about the schools and parents’ perceptions towards

Shona as a language of instruction. According to Chivhanga (2014, p. 40) “The success of using Chishona as a medium of instruction in the teaching of mathematics in primary schools depends on people’s attitudes and desire to actually implement it.” The feelings expressed imply that instruction in Shona may become futile in teaching mathematics because of the negative attitudes from the implementers and parents.

The teachers further explained the advantages of using English over Shona. Joanne, a grade 1 teacher from a HDA school said that children become marketable in industries, universities and internationally if they are proficient in English language, hence she would prefer English over Shona. By and large, the interview conversations with the teachers revealed that most teachers were against the use of Shona in the classroom because English is regarded very highly in the country. Such views may not support the use of Shona as a medium of instruction in teaching mathematics. According to Chivhanga (2014), English language has remained a highly regarded language, in Zimbabwe. It is a language that permits entrance into the industry and universities and ultimately, proficiency in the language is associated with better opportunities in life and better side of knowledge. Gudhlanga (2005) also infers that most people in Zimbabwe have negative attitudes towards the use of African languages as languages of instruction in education because children are required to pass English in order to obtain a full "O" level certificate. This is likely to impact negatively on the significance of Shona in education, particularly at infancy level.

Chivhanga (2014, p. 60) hence, wrote, “Each language to be used must serve a purpose, otherwise there would be no justification for human, material and financial resources expended on teaching a language for its sake...” Now, if Shona is lowly regarded in the country, the purpose of using it in mathematics may be defeated. These deliberations were also supported by the lesson observations done. Lilian, Vee and Charity taught their lessons in English and pupils responded very well.

However, Tendai, a grade 1 teacher from the same school as Lilian, preferred to teach mathematics in both English and Shona, that is, teaching a concept in English and repeat it in Shona for understanding (Code-switching). She however agreed that her pupils understood English and they enjoyed the language. Tendai remarked as follows:

“They can speak English very well but they do not understand English instructions. They are happy when teaching them in English but English only is what gives them problems. So I mix....”

The idea of code-switching was assented to by most teachers in the rural and HDA schools. Chips a grade 2 teacher in the HDA had this to say;

“I will introduce a mathematics lesson in English and repeat in Shona. The pupils understand simple English. So you use both languages but more inclined to English. Complete Shona does not come out properly.”
Most teachers who were of the idea of mixing the languages had several reasons that included better understanding of concepts and concurrent learning of both languages. Code-switching was also found to be helpful in teaching mathematics effectively as indicated by the observations result where students (with a poor English background) were participating more in the lessons where both Shona and English were used. Jegede (2011) hence, contends that code-switching is a useful way of transferring knowledge to the learners in a multi-lingual mathematics classroom. However, the conversations with the participants show that Shona was only used as a second option when English fails. This implies that in the case where pupils had no problems with instructions or conception, English language would be used throughout the lesson. The problem with code-switching for these classes, however was time shortage to cover a topic.

The research observations also established that some learners with the rural background were struggling to answer questions in English, some never attempted to use English, worse still understanding the concepts taught in the adopted language. The inability to share a language (English) fluently made communication between the teacher and the pupils difficult. Hence, the teachers resorted to using Shona in the classrooms to facilitate learning. Susan, a grade 2 teacher from the rural areas said:

“They understand Shona better than English. I sometimes try to teach in English but they understand better in Shona. We mix with a bit of English but I use Shona most of the time.”

The fact that the less privileged children understood Shona better than English, whilst the better privileged ones were also better in English, denotes Shona as a lowly esteemed language in the country. This assessment is likely to kill the desire to learn mathematics in Shona. After being asked to explain the challenges they experienced in teaching mathematics in indigenous language, the concerns raised by teachers in general included the translation of terms from English to Shona. Lilian had this to say;

“It is difficult to translate English terms like ‘mass, division, quarter, etc to Shona. How can you put that in Shona? Like right now, I am teaching comparisons, ‘light, lighter, lightest’, they are difficult to explain in Shona.”

Charity supported the idea by saying;

“Some words are difficult to interpret, for example, sum, fraction and many more. Some of these terms confuse the pupils when you try to define them in Shona for the pupils. It is better if I say ‘half’ (1/2) than to say ‘cheka nepakati’ (cut in the middle). How would you explain 2/3?”

Joanne, a grade one teacher is also of the same opinion. She retorted,

“…… look here, (showing a text book), its written ‘ordinal numbers’. You want to convert this to Shona, hatipiwi interpretation yacho in Shona (we are not given the shona interpretation)…..”

The problems portrayed by the teachers exhibit the vocabulary limitations in Shona to explain the mathematical concepts. This means Shona tends to lack the terms, structures and categories used to teach school mathematics, which suggests that resorting to Shona consistently may curtail understanding of some mathematical concepts.

The other challenge that was raised by all the participants was the discord that existed between the language expected to be used to teach mathematics (Shona) to the infants and the language in the text books used for reference. Whilst the teachers were encouraged to use Shona as the medium of instruction, the text books were all written in English, and the assessment was done in English. Although Mutasa (2003) asserts that learning takes longer when using a foreign language than in the mother language, the results of the interviews and the observations revealed that pupils taught in Shona found it hard to link the concepts taught in Shona to the questions asked in English, and consequently, the learning process became equally long. Shirley remarked;
“Yes, they say teach in Shona but the tests are set in English. Like grade 1, second term, they write the tests in English. If you concentrate with Shona, how will the pupils perform? It confuses the pupils”

Despite using Shona to teach mathematics, Shammy and Joanne concurred that they had challenges with the exercises that were given in English while students are taught in Shona.

The results of the observations also revealed that sometimes language has very little impact on the development of mathematics knowledge among infants. During observation, one of the teachers, Joanne, was teaching the topic ‘Money’. She was teaching the concept that 10 cents can be made up of different denominations of money, for example, 10c = 1c + 1c + 1c + 1c + 1c + 1c + 1c + 1c + 1c + 1c. Or 10 cents = 2 ‘five cent coins’, that is 10c = 5c + 5c, etc. Pupils were given different coins in groups and were taught in Shona with some bit of English. Towards the end of the lesson, the researcher (R) had some conversation with the pupils to test understanding.

R: How many one cent coins make 10 cents? [in English]

Student A: 3, B: 10, C: 2, D: 1

Only four students (A, B, C, D) responded to the question and the rest were quiet. It was assumed that the students’ lack of the English language fluency stifled their understanding. Hence, no feedback was given before the same question was asked in Shona;

R: Ma cent mangani anotipa 10cents/anowanikwa mu 10cents [in Shona]

Again, only 3 pupils wrongly responded to the question and the rest looked confused. The failure to get the right answers after the question had been asked in both languages could be ascribed to the misconception of ideas, which could be due to the methodology used and not necessarily the language used. The same trend was observed in the other two lessons observed. The observations point to the fact that the development of mathematics knowledge is not always impaired by the language used in the classroom. Charity and Vee were in consensus when they explained that they also had cases where children understood both languages (English and Shona) but still failing to perform well.

The study further found that in some of the schools where mathematics was taught in English, the teachers were somewhat side-tracked by the improper use of English language by the learners and tended to focus more on the language than the learning of mathematics. The following excerpt is an example of the conversation that was observed in one of the lessons with the grade 2s.

Teacher (Vee): What is 3(4) (meaning 3 sets of 4)? Someone to illustrate on the board.

Student: We make 3 sets and then counted……….. (teacher interjected)

Teacher: No, ‘and then count…….’

Student: We makes 3 sets…….

Teacher: Say, ‘we make……and then count’

The conversation went on a little bit longer because the student continued to make some grammatical mistakes whilst the teacher continually tried to correct her language. The teacher was focussing more on the appropriateness of the English used than the mathematics concepts to be learnt. According to Moschkovich (2012), instruction in mathematics should focus on enhancing mathematical reasoning and not accuracy in using a language, which suggests the teacher was supposed to focus more on the concept being illustrated. That would save time to cover adequate mathematics content within the mathematics period. The implication of this finding is that language should not be the focal point in teaching mathematics, as long as the child has basic knowledge of the language to communicate the mathematical concepts.
Teachers were also asked about their general views towards the “updated Curriculum” in the Zimbabwean schools. Their sentiments exhibited dissatisfaction across all the subjects including mathematics. The teachers’ feelings showed that there were still some inadequacies in the updated curriculum that needed to be spruced up. They mentioned inadequate training to implement the curriculum, textbook shortages (some schools only had the teacher’s copy in a class of 35 students), lack of follow-ups to ensure the curriculum was being properly implemented and the use of Shona was also not supported by the textbooks available.

CONCLUSION AND RECOMMENDATIONS:

The study found that whilst the use of indigenous languages can be a prudent idea to facilitate the learning and teaching of mathematics to infants, the teachers view the education system in Zimbabwe as inadequately equipped for the implementation of such a curriculum because of the unavailability of supporting materials, lack of skills to implement the curriculum and the low recognition that Shona is receiving in education as a medium of instruction. The study also established that the success of using Shona as a medium of instruction in the teaching of mathematics in primary schools depends on practitioners’ attitudes and desire to actually implement it. This study hence recommends that the language used to teach mathematics should be supported by the materials available. Bamgbose (1991, p. 72) wrote “No matter how large the population of speakers of a language is, it is only when the language has been reduced to writing and materials made available in it, that it can be used in education.” Lack of supporting materials makes it difficult to use Shona in teaching and learning school mathematics. The use of Shona in teaching mathematics also needs to include the consideration by the ministry of whether the implementers are well prepared for their role and whether what they are required to achieve is feasible.

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ABSTRACT – This paper briefly reports on three recent visualization processes in mathematics education case studies that trialled visualization teaching approaches in different contexts within Namibia. All participating teachers were selected purposefully. The studies found that visualisation processes play an essential role in enhancing understanding of varied mathematical concepts at all levels of school education in these selected Namibian mathematics classrooms. We conclude that as much as visualization is concerned with physical images, products and diagrams, it is also about mental processes in solving problems.

Keywords: Visualisation; Mathematics; Visual Models; Gestures

INTRODUCTION

This paper briefly reports on three completed instrumental cases on visualization processes in three different grades/phases in the school curriculum on fractions, quadrilaterals and the use of gestures that were done in Namibia between January 2017 and October 2018. The studies were conducted under the auspices of the Visualization Processes in mathematics education (VIPRÔmaths) research project that aims to research the effective use of visualisation processes in mathematics classrooms in South Africa, Namibia, Zambia, Switzerland and Germany. This paper wishes to advocate for the VIPRÔmaths project that has at its core a research programme that interrogates diverse aspects of visualization processes in the context of teaching and learning mathematics. Overall, the VIPRÔmaths project (www.ru.ac.za/mathsedchair and www.nammaths.com) is framed by research agendas that fall into four main clusters; visualization as a pedagogy, visualization and cognition, visualization as a key mathematical construct, and visualization as a medium for epistemological access. Currently it involves a total of fourteen MEd and seven PhD students from South Africa and Namibia. Two of the three studies briefly outlined here were all crafted around a dedicated teacher intervention program. It was the aim of each study to generate new knowledge in and insights into strategically harnessing visualisation processes in selected Namibian mathematics classrooms to make a positive contribution to improving classroom practice and pedagogy in Namibia. The newly revised mathematics curriculum in Namibia intimates that mathematics should be made visual to all learners (Namibia: Ministry of Education (MoE), 2015).

As the primary goal of schooling is the provision of meaningful learning environments, the teachers’ primary task is thus to find and use teaching approaches that promote conceptual understanding of mathematical concepts, ideas and relationships. This has implications for every teacher in terms of how and what he/she teaches. Although the Namibian national curriculum for basic education compels mathematics teachers to be “creative and innovative to produce their own teaching and learning materials linked to practice” (Namibia. Ministry of Education (MoE), 2010, p. 6) at all school levels, most mathematics teachers still find it difficult to create and make use of teaching aids and materials. Miranda and Adler (2010) observe that “Namibia is one of the many African countries, in which the use of manipulatives in mathematics classrooms is not a common practice” (p. 17). This is corroborated by our experiences that confirm that apart from diagrams and figures encountered in the prescribed textbooks (Nghifimule, 2017); meaningful visualization processes are sparsely used in Namibian mathematics classrooms. It is thus the objective of the various intervention programs central to the VIPRÔmaths project to encourage increased and sustained use of visualization processes to enhance conceptual understanding.

VISUALISATION

Visualisation is generally accepted and considered as helpful in mathematics education because of its diverse pedagogic, cognitive and epistemic purposes. We consider Arcavi’s
Arcavi (2003, pp. 216 - 7) describes mathematics as a human and cultural creation that deals with objects and entities quite different from physical phenomena and relies heavily on visualisation in its different forms and at different levels, far beyond the obviously visual field of geometry, and spatial visualisation. We thus concur with Zimmerman and Cunningham (1991) who noted that visualisation in mathematics is not merely an appreciation of mathematics through pictures or visuals, but instead it supplies depth and meaning to understanding mathematics, serving as a reliable guide to problem solving, and inspiring creative discoveries.

Visual representations play a crucial role in understanding and making sense of mathematics. Some of the ways in which visualisation processes in mathematics education have been used include making use of one’s own visual images when posing and solving mathematics problems (Bishop, 1989); constructing concept maps as visuals (Presmeg, 2006); using visualisation as a teaching strategy; and designing “visualities” of mathematical tasks themselves. Boaler (2016, p. 1) argues, “when students learn through visual approaches, mathematics changes for them, and they are given access to deep and new understandings.”

It is expected from an effective teacher that she develops and employs appropriate visual materials or use ready-made materials such as teaching aids and manipulatives in order to enrich her teaching. As stated by Boaler (2016, p. 5), “teachers who emphasize visual mathematics and who use well-chosen manipulatives encourage higher achievement for students, not only in elementary school...” Visualisation in mathematics pedagogy thus refers to the deliberate use of visuals to promote a deep understanding of concepts “both from teachers introducing mathematical ideas visually, and students using visuals to think and make sense of mathematics and connecting previously unconnected theories in mathematics,” (Boaler, 2016, p. 5, 7). Röskens and Rolka (2006) assert that visualisation can be a powerful tool to explore mathematical problems and to give meaning to mathematical concepts and the relationship between them, and subsequently reduce complexity when dealing with a multitude of information.

This paper very briefly reports on three recent case studies that trialled visualization teaching approaches in different contexts within the framing of three intervention programmes. Except for Nelao’s intervention programme, each of the other two consisted of a set of workshops that firstly orientated the selected participants in visualization processes in mathematics, secondly in integrating these processes in the teaching of fractions, quadrilaterals and basic geometry respectively, and thirdly in designing and implementing a series of lessons in these mathematical concepts. All the participants were selected purposefully and were located in close proximity to the researchers.

**AUNE’S PROJECT AND FINDINGS - FRACTIONS**

This study, guided by constructivist theory, explored the use of three visual models (area model, number line model, set model) by three selected secondary school mathematics teachers in the Khomas region in their teaching of common fractions to enhance the conceptual understanding. The overarching aim of this study was to create awareness amongst mathematics education teachers about the role of visualisation processes in the teaching and learning of common fractions and to trial the three visual models. This mixed method study firstly employed a survey questionnaire with all mathematics teachers in the region (forty-six teachers) to seek responses on the extent to which the respondents used
visual models when teaching fractions. Secondly, the study used stimulated recall interviews with the three selected Grade 8 teachers on how they used the three visual models in their day-to-day teaching of common fractions because of participating in an intervention programme that interrogated the three visual fraction models.

Although 80% (n=46) of the teachers in the survey indicated that they rarely used visual models to teach fractions, many agreed that the use of visual models such as area, number line or set models to teach common fractions was important. The 76% of the surveyed teachers indicated that visual models can make abstract concepts concrete and can clarify mathematical ideas whose meanings are difficult to comprehend. In addition, teachers in the survey further asserted that visual models attract learners' attention and stimulate learners' interest in learning mathematics. They further argued that visual models also make mathematics fun and practical. Visual models enhance deep conceptual understanding. They highlighted that visual models help learners to grasp mathematical concepts without difficulty as they learn better by seeing visuals rather than symbols.

It was noted that despite interrogating all three fraction models in the intervention programme, the three participating teachers were reluctant to use the set model. This was followed up in the interviews. Some of the teachers' responses are given below.

Ms Nalo had this to say:

Ok, to me both models help learners to understand, only that each one of them has a kind of a challenge but they are both easier to use than the set model. I used only two models, the area and number line only in my teaching. I tried the set model and realised that it is difficult. But the area model is quite easy because I could connect easily with other concepts. Same with the number line I could also link with number sense but the set model is not easy to understand. (NaSRI 96-104)

On the same note, Mr Malele pointed out that:

….the two models that I have used, they are both helpful any way. But I have seen that using area models is quite easier than the other two. The number line when you draw it you have to divide the number line into continuous whole which is sometimes in my teachings made learners a bit confused. But when I have used the area model, where you just draw separate wholes and you divide them into parts as given by the fractions that makes learners to understand it much better compared to the number line model. The set model I did not use it. I found it difficult to use with my learners. I would need more time to study it first. (MaSRI 123-127).

All three teachers used only the area and the number line models, and not the set model, to teach their lessons on fractions that they prepared in the intervention programme. These were mostly drawn on the chalkboard except for one teacher who used PowerPoint to present the addition and subtraction of fractions using the number line model. Two teachers preferred drawing the models while their learners were present in class, and one preferred to draw the models before learners came to class. Observations and feedback from the teachers revealed that learners tended to follow and understand better when models were drawn during the lesson, unlike when they find models already drawn. This was because the drawing was always accompanied by teacher explanations. This has implications on the use of already made visuals like charts, PowerPoint presentation slides and even textbook use when teaching mathematics.

Mr Mose, for example indicated that:

…the area model is easy and convenient to use. With the area model, we were cutting into smaller pieces, of equal parts and of a different colour. The area model is the best and it is user friendly. Learners were able to draw and play around with it unlike with the number line and set model. The number is also easier but I prefer the area model. The other one, the set model, aaah I avoided it. It is confusing. (MoSRI 37-41).
The dominance of the area model in the observed classes was due to this model being easier to draw and use, and the ability to link the area model to prior knowledge. Ms Nalo argued that the number line model was not as easy to use as the area model when adding or subtracting fractions of different denominators. On the other hand, Mr Malele pointed out that a number line is confusing because of the continuous whole. All the three teachers avoided the set model. They considered it very difficult for them and the learners to understand.

**GIVEN’S PROJECT AND FINDINGS - QUADRILATERALS**

This study aimed at investigating and analysing the effective use of a Geoboard by three selected teachers as a visualisation tool in the teaching of quadrilaterals in Grade 7 as a result of them participating in an intervention programme in the Kunene Region. The study was also guided by the constructivist theory. Qualitative data was collected through observations and interviews from the three Grade 7 mathematics teachers in three primary schools.

Selected teachers participated first, in two workshops that aimed at designing their own Geoboards. The second set of three 1-hour workshops were aimed at orienting and familiarising teachers on how Geoboards may be used to construct and manipulate various types of plane shapes. They were also used to design a learning programme that consisted of six lesson plans. The teachers found the Geoboard useful in enhancing the teaching and understanding of properties of quadrilaterals. It served as a powerful visualization tool to illustrate, explore and discuss the properties of quadrilaterals. Its use aided motivation and improved participation during teaching. The teachers indicated that the Geoboard enabled a dynamic learning environment as learners were noted turning their boards in various directions and orientations to understand the properties of quadrilaterals they had constructed.

Mr Jones indicated that:

*With the Geoboard it was very easy because you just take the rubber bands and you can adjust them even learners could adjust them the way they feel like. I mean extend the corners of a square or to put them inside to form a rhombus.* (JoSRI; 56-59)

Ms Ruth noted that her:

*The learners turned around the geoboard and then counted the pins at the now bottom. Instead of four pins now she had six, of the same trapezium. Although only the position was turned around it remained a trapezium yet the learner looked at it from a different angle. Unlike the way it was placed on the Geoboard.* (RuSRI; 44-57)

Ms Smith pointed out that:

*Learners were sharing the Geoboards in groups and every one was interested in doing something, in constructing something, everybody wanted to touch here and there. Therefore, everybody was actively participating there although not all the members of the group knew exactly what they were constructing. They were so eager to do and finish the individual activity. Everybody was eager to do it on his or her own.* (SmSRI; 93-97)

Despite the overwhelming positive reaction to using the Geoboard, numerous interesting challenges had to be overcome. The teachers found that the size of the Geoboard as a teaching aid had to be considered. It was important that the different coloured elastic bands that were used to construct the quadrilaterals were visible to the entire class.

Some geometric concepts were not so easy and apparent to demonstrate on the Geoboard. Mr Jones gave an example of lines of symmetry. Learners had difficulties constructing a line of symmetry when they constructed a square that had sides composed of an even number of pins.

Mr Jones, for example indicated:
What I realised is that if you are making a square using rubber bands on the Geoboard you must be very careful with the pins. Because the pins should be equal so that when they use the rubber bands to make the line of symmetry, they must put it on the middle pins. So, if it is not like that, it becomes a problem because it won’t give the exact properties (JoSRI, 147-153).

Mr Jones thus suggested that using pins and rubber bands for illustrating the concept of lines of symmetry on the Geoboard would work well when an odd number of pins are used. This is because of the existence of a clear set of pins in the middle. He noted that this was not the case when an even number of pins on the sides of a shape were used. Learners’ failure to locate a line of symmetry on the Geoboard may have been caused by teachers. It seems they did not take into consideration the issue of even and odd numbers of pins on the Geoboard before giving the activity of symmetry to learners. Sarama and Clements’ (2016) advice when it comes to the use of manipulatives, teachers should make sure that there is a connection between the manipulative and the concept related to its representation. However, it seems this was not heeded to as the anticipation of the problem that could arise regarding the use of an even number of pins was overlooked.

NELAO’S PROJECT AND FINDINGS - GESTURES
The third study was guided by the observation that when teachers talk and teach, they very often gesture, and those gestures often reveal information that may not be apparent in their verbal speech. In this study, gestures refer to bodily movements, usually with our fingers, hands and arms that accompany a verbal explanation or statement that were used to support, exemplify or illustrate what teachers were saying. This qualitative interpretive study framed by an enactivist perspective aimed to investigate the nature and role of gestures that three purposeful selected junior primary phase (Grades 0-3) teachers used in the teaching of mathematics. The study also aimed at understanding the selected mathematics teachers’ views on the roles of their gestures as visualisation tools in the teaching of mathematics. Data was collected through classroom video-recorded observation and stimulated recall interviews.

Nelao’s findings were based on 30 lesson observations across an entire term involving three foundation phase teachers. Her analytical framework, which she imposed on her video-recorded lessons, was grounded in McNeill’s (1992) classification of gestures which included pointing (deictic) gestures, iconic (illustrative) gestures, metaphoric gestures, beat (motor) gestures and symbolic (emblem) gestures. This study aligned itself with Castellon and Enyedy’s (2006) argument that gestures can be important visual resources that can play a valuable role in the teaching-learning process of mathematics. Very pertinently, they can be used as an important bridge between imagery and speech. They may be seen as a nexus bringing together action, memory, speech, imagery and mathematical problem solving (Alibali & Nathan, 2012).

The analysis was two pronged where firstly a frequency analysis was done across all the participating teachers for all the 30 lessons – see table 1, and secondly a qualitative analysis of the interviews that were conducted with each of the teachers.
In general, the participating teachers felt that the use of gestures provided for a learning environment that was dynamic and rich. Gestures enabled the teachers to reinforce, support, illustrate and strengthen concepts they were trying to teach. Gestures facilitated both instructional and conceptual communication, the former being communication that refers to procedures of what needs to be done, and the latter being communication that is mathematical referring to concepts and content. The study concluded by acknowledging that gestures are recognized as legitimate teaching resources and strategies, provided they are used strategically and meaningfully.

CONCLUSION

It seems as if we take it for granted that visuals are integral to our interpersonal and teaching communication repertoire. Visuals are closely linked with language and thought, and therefore with teaching and learning. There is increased recognition that visualisation is not meant for illustrative purposes only, but is a key component of reasoning and mathematical thinking. As much as visualization is concerned with physical images, products and diagrams, it is also about mental processes in solving problems. As the three studies above illustrated, there is room for much research about how best to harness visualization processes in all its facets in the teaching and learning of mathematics.

REFERENCES


AN EXPLORATORY STUDY ON THE MINDSETS AND MOTIVATION OF MATHEMATICS TEACHERS
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ABSTRACT – Teachers’ mindsets have an influence on their teaching approaches, which could either motivate or demotivate learners to perform in mathematics. This paper reports on the mindsets and motivation of eight senior phase mathematics teachers conveniently selected from four schools in Gauteng-West. This study was exploratory. A questionnaire was used to collect biographical information and frequencies of participants’ perceptions on their mindsets and motivation and one-on-one interviews to collect qualitative data. The findings reveal that teachers’ perceptions of their mindsets and their motivation to teach mathematics differ from their enacted mindsets and motivation in the classroom.

Keywords: Mathematics; Mindset; Motivation; Teachers; Senior phase.

INTRODUCTION
Modern society enforces a fixed mindset on teachers by valuing ability as inherited processes for achieving success (Dweck, 2010). Teachers’ effectiveness to teach mathematics is often measured by society against learners’ performance (Tsanwani, Harding, Engelbrecht, & Maree, 2014). Such a mindset creates a belief that achievement is more important than hard work and perseverance, which could be detrimental. Some teachers may also perceive their own practices as effective when their learners have good procedural fluency in mathematics and obtain good results in the subject. On the other hand, others may regard them as successful if their learners have a good conceptual understanding and show progression in their learning of mathematics. A teacher’s mindset, whether fixed or growth, has an influence on how their learners perform in mathematics (Jantjies & Joy, 2016). Teachers can either motivate or demotivate their learners to engage in mathematics. According to Dweck (2012), learners taught by a teacher with a fixed mindset, sustain their academic performance, while poor-performing learners start excelling if taught by a teacher with a growth mindset. Boaler (2013) agrees that a growth mindset can enhance learners’ attainment and ensures equality in the classroom. In particular, Boaler (2013) argues for more open assessment tasks in mathematics, which allow for the valuing of mistakes as an opportunity for learning achievements.

This paper argues that teachers’ perceptions of their mindsets and their motivation to teach mathematics differ from their enacted mindsets and motivation in the classroom. Thus, this paper aims to establish the mindsets and motivation of senior phase (SP) mathematics teachers. The research question is: What are SP mathematics teachers’ mindsets and motivation pertaining to their teaching of mathematics?

THEORETICAL BACKGROUND
A mindset can be explained in terms of implicit theories, which are defined as “core assumptions about malleability of personal qualities” (Yeager & Dweck, 2002, p. 303). The entity and incremental theories are two opposite beliefs on intelligence equated to fixed and growth mindsets (Gutshall, 2013). Dweck (2010) argues that people have varying degrees of mindsets ranging from a fixed to a growth mindset. People with a fixed mindset, usually focus on their abilities, rather than effort, thus a person’s intelligence is believed to be unchangeable, or an entity. In contrast, those with a growth mindset believe that although ability may contribute to success, it is a quality that one can develop over time with effort, thus intelligence is incremental. People with a growth mindset are always on the way of learning new things and improve themselves. They are motivated to do things for themselves that make them happy.

People with a fixed mindset avoid taking risks as they are afraid to appear inadequate when undertaking a task (Mindsets: How to motivate students (and yourself), (2012)). These
teachers usually follow the curricula to the point for a specific grade and do not necessarily allow for exploration or investigations (Pritscher, 2010). They believe struggle is a sign of deficiency as a person is born with intelligence. Thus, mathematics should only be taken by those who have a talent to calculate and solve problems.

 Teachers with growth mindsets motivate learners to learn from mistakes and encourage questioning by learners. These teachers stimulate learners’ imagination, which allows for new discoveries imperative for development (Pritscher, 2010). These teachers value praise and feedback. According to Dweck (2015), a growth mindset is a consistent process that changes as thinking skills develop.

 Gutshall (2013) claims that there is a link between mindset and motivation by noting that mindset influences learning via performance goals and motivation. A person’s mindset often influences the reasons why certain behaviours occur. Whilst happiness varies from one person to another, the motivation to complete certain activities is often dependent on the type of mindset a person has. The motivation to complete an activity is often based on whether doing the activity will make the person happy or not.

 Motivation is the procedure whereby a person try to achieve or avoid a goal-directed activity that has been initiated internally or externally (Thomson, Turner & Nietfeld, 2012). Intrinsic motivation relates to a person’s values about attaining success, thus an innate desire to engage in behavior for one’s personal enjoyment. On the other hand, extrinsic motivation refers to feelings of external pressure resulting from a desire for rewards or avoidance of criticism (Van den Berghe, Soenens, Aelterman, Cardon, Tallir & Haeren, 2014). Thus, extrinsic motivation is about doing tasks by knowing they will be externally compensated. Mindsets and motivation can be changed and are influenced by a person’s environment (Mindsets: How to motivate students (and yourself), (2012)). Therefore, teachers should offer learners an environment in which they could motivate themselves to become autonomous in their learning of mathematics by portraying a growth mindset.

 A few studies on mindsets have been conducted over the past decade. Pawlina and Stanford (2011) conducted a study and found that children who are able to endure challenges, have also the power to control the outcome of a learning experience. They recommend an investigation into this power in terms of motivation. Gutshall (2013) revealed that teachers who thought that their learners’ intelligence was fixed offered their learners less support and encouraged them to find their own solutions, while teachers who believed that intelligence was more malleable, were far more supportive and reported instructional goals that enabled their learners to solve problems effectively. A study in a school that was not achieving found that teachers were frustrated and less motivated when teaching their subject (King-Sears & Baker, 2014). It was found that the teachers often questioned their abilities and whether they had made the correct career choice. The mindset these teachers have can be classified as a fixed mindset. They view their teaching skills as a fixed event, unable to adapt to the learners abilities. They also view their learners as having a limited potential. A researcher in Germany looked at teachers’ mindsets at the beginning of a school year and then monitored learners’ achievement throughout the year (Dweck, 2010). It was found that low-achieving learners who entered a class with a teacher with a fixed mindset left as low achieving learners. The opposite occurred in a class where the teacher had a growth mindset. It was found that low-achieving learners improved their marks and some even became high-achieving learners. Dweck (2015) found that if learners are taught with a growth mindset, their motivation changes and their grades changes.

 Research has also looked at how motivation influences students in the classroom, but very little research takes the teacher into consideration (King-Sears & Baker, 2014). A study in China focused on the initial education stage and explored the beliefs of teachers (Gillett, et al., 2012). They looked at both the intrinsic and extrinsic motivation of the teachers and their effects on performance. They found there was a clear link between what drove a teacher to teach and the performance of the learners. Perry, Brenner, Collie and Hofner (2015)
investigated whether and how motivation supports teacher effectiveness by exploring what distinguishes teachers who thrive in contexts with others who find teaching challenging. They found teachers’ motivation is related to their feelings of teaching efficacy, commitment and engagement. However, none of these studies were conducted specifically in the mathematics discipline and within a South African context.

**RESEARCH METHODOLOGY**

This exploratory study used a questionnaire to collect biographical information and frequencies of participants’ perceptions on their mindsets and motivation and one-on-one interviews to collect qualitative data. The questionnaire was based on the original survey from Dweck (1999) determining people's mindsets consisting of six items, and an amended decomposed version of Lemos and Verissimo (2006) of the Scale of Intrinsic versus Extrinsic Orientation in the Classroom comprising 12 items. The items were measured with a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The one-on-one interviews were semi-structured and questions were prepared focusing on teachers’ perceptions about the relationship between their mindsets and motivation concerning the teaching of mathematics.

The sample consisted of eight SP mathematics teachers (N = 8) conveniently selected from four schools in Gauteng-West, specifically in the Krugersdorp area. One school was an ex-model C school, while the other three were private schools. These schools were in a 10 kilometer radius. Participation was voluntary. Although all eight participants agreed to complete the questionnaire, only three of them, each from a different school, participated in the interviews due to other participants’ involvement in preliminary examinations, which limited their time.

The sample of eight participants consist of three males and five females. Seven of the participants were white, while only one was black. The ages of four teachers were between 24 and 30, while one teacher was in the 30s, one in the 40s, one in the 50s and the oldest teacher was 63 years old. Four teachers’ home language was English, three spoke Afrikaans, and one was Ndebele speaking. Two participants had a diploma/degree, but not in mathematics. Five participants had a first degree majoring in mathematics and one extended his/her qualification with an Honours degree in mathematics.

The questionnaire complies with validity and reliability measures as it is a standardised instrument. However, face validity was ensured by means of a pilot study where co-researchers checked the questionnaire in terms of language and accessibility. The interviews were developed with a focused structure to ensure that interview questions relate to the research question. To ensure consistency, data were collected in similar environments, after working hours, inside a classroom and the same questions were asked to all three participants. Ethical clearance was obtained from the University of Johannesburg (Ethical clearance number: 2015-025) and the researcher complied with all ethical measures.

**RESULTS**

The biographical information and frequencies of participants’ perceptions on their mindsets and motivation were captured in Microsoft Excel. The results per construct were tallied and summarised. The average mean and standard deviation were calculated for each item for all eight participants. Table 1 illustrates the frequencies (as percentages) of the participants’ perceptions on their mindsets and motivation.
Table 1: Frequencies of SP mathematics teachers’ perceptions on their mindsets and motivation.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Items</th>
<th>SD</th>
<th>D</th>
<th>Neutral</th>
<th>A</th>
<th>SA</th>
<th>X</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed mindset</td>
<td>1-3</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>2.17</td>
<td>1.076</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(41.6%)</td>
<td>(17.5%)</td>
<td>(2.5%)</td>
<td>(12.5%)</td>
<td>(2.5%)</td>
<td>(43.4%)</td>
<td></td>
</tr>
<tr>
<td>Growth mindset</td>
<td>4-6</td>
<td>0</td>
<td>1</td>
<td>8</td>
<td>10</td>
<td>5</td>
<td>3.79</td>
<td>0.784</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(2.5%)</td>
<td>(33.3%)</td>
<td>(41.7%)</td>
<td>(20.8%)</td>
<td>(75.8%)</td>
<td></td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>8-10, 13-15, 18</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>24</td>
<td>26</td>
<td>4.34</td>
<td>0.749</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(1.8%)</td>
<td>(8.9%)</td>
<td>(42.9%)</td>
<td>(46.4%)</td>
<td>(86.7%)</td>
<td></td>
</tr>
<tr>
<td>Extrinsic motivation</td>
<td>7, 11-12, 16-17</td>
<td>14</td>
<td>6</td>
<td>9</td>
<td>7</td>
<td>4</td>
<td>2.53</td>
<td>0.892</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(35.0%)</td>
<td>(15.0%)</td>
<td>(22.5%)</td>
<td>(17.5%)</td>
<td>(1.0%)</td>
<td>(50.6%)</td>
<td></td>
</tr>
</tbody>
</table>

X, average response (means); SD, Standard deviation

The recorded interviews were transcribed and inductively coded and categorised. Thereafter, the categories were deductively sorted according to four constructs, namely fixed mindset, growth mindset, intrinsic motivation and extrinsic motivation. Table 2 displays the themes, categories and codes transpired from the interviews with three participants.

Table 2: Themes, categories and sub-categories transpired from the interviews.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Category</th>
<th>Codes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed mindset</td>
<td>Experience and teaching</td>
<td>Narrow-minded</td>
</tr>
<tr>
<td></td>
<td>Planning</td>
<td>Rigid and descriptive teaching styles</td>
</tr>
<tr>
<td></td>
<td>Time management</td>
<td>Time</td>
</tr>
<tr>
<td>Growth mindset</td>
<td>Goal setting</td>
<td>Avoid setting unrealistic goals that set you up to failure</td>
</tr>
<tr>
<td></td>
<td>Solution orientated</td>
<td>Solutions can be developed in numerous creative ways</td>
</tr>
<tr>
<td></td>
<td>Challenges</td>
<td>Embrace failure openly</td>
</tr>
<tr>
<td>Intrinsic motivation</td>
<td>Positive attitude</td>
<td>Enjoys teaching and gets motivated by learners who want to learn</td>
</tr>
<tr>
<td></td>
<td>Value change</td>
<td>Proud to see the changes in learners’ understanding and enjoyment of mathematics</td>
</tr>
<tr>
<td></td>
<td>Internal motivation</td>
<td>Internal reinforcement</td>
</tr>
<tr>
<td>Extrinsic motivation</td>
<td>Rewards</td>
<td>Ability of students that can improve</td>
</tr>
<tr>
<td></td>
<td></td>
<td>External reinforcement from learners</td>
</tr>
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</table>

DISCUSSION OF RESULTS

Almost half of the responses (10 out of 24; 41.6%) in the questionnaire indicated that participants strongly disagree that they have a fixed mindset ($X = 2.17; SD = 1.076$). On contrary, 20.8% (5 out of 24) responses showed that participants strongly agree that they possess a growth mindset ($X = 3.79; SD = 0.784$). However, 33.3% (8 out of 24%) responses were neutral about owning a growth mindset. Although most responses indicate that participants agree that they do not have a fixed mindset, they are not always confident that they have a growth mindset.

However, from the interviews it can be derived that two of the three participants enacting a fixed mindset in their classrooms. Participant A viewed mathematics as “a fundamental building block ... everything has a solution ... someone understand something ... to follow rules is very important”. Also, participant B implicitly indicated that he/she has a fixed mindset by claiming that “I believe at the moment my level of intelligence doesn’t restrict my teaching, but my experience does. My personal understanding of the subject is where it should be”. Dweck (2015) agrees that a fixed mindset is when people believe that their traits, such as intelligence, form their basic abilities. Participant B also adheres strongly to the curriculum by uttering that “they have to stick to the curriculum if they want to get marks in their finals, so their methods has to be mathematically correct, which is an indication that
he/she has a fixed mindset. According to participant B, he/she is motivated “to do better from
term to term” by setting termly goals, which indicates that performance is important to
him/her. Only participant C showed some evidence of a growth mindset by claiming that
he/she believes “that mathematics can be taught and learned regardless of backgrounds …
It needs commitment and perseverance”. He/she also claim that “learners are encouraged to
solve mathematics the best way they can”. Duckworth, Peterson, Mathews and Kelly (2007)
also acknowledge that a person shows characteristics of a growth mindset if he/she has fiery
passion and perseverance to reach long term goals.

Although most participants did not strongly agree that they have growth mindsets, most of
the responses (26 out of 56; 46.4%) reveal that participants strongly believe they are
intrinsically motivated to teach mathematics ($X = 4.34$; $SD = 0.749$). A smaller number of
responses (14 out of 40; 35.0%) strongly disagree that they are extrinsically motivated to
teach mathematics ($X = 2.53$; $SD = 0.892$).

From the interviews, however, only two of the three participants mentioned how they
perceive motivation. Both of them value extrinsic motivation. According to participant A, by
“seeing someone understand something … is very rewarding for me”, but he/she expects
learners to be intrinsically motivated, by responding that “I do try to let them challenge
themselves individually to always try and improve their results. …as each student has their
own standard. I get the learners to set intrinsic goals, and make sure their goals are realistic
and reachable”. Participant B holds the view that extrinsic motivation should succeed intrinsic
motivation by claiming that he/she

using a lot of positive reinforcement in your classroom is essential, because I believe that
once the learners have a love for maths and a belief that they can do it, then when they get
challenged, they will have the necessary self-belief and self-drive to work hard.

However, he/she “also enjoy[s] the fact that learners can discover the theorem by
themselves”. Barto (2013) concurs that intrinsic motivation is associated with teachers’
enjoyment and doing things naturally, however, they also enjoy the rewards of it, which
confirm that teachers can appreciate both intrinsic and extrinsic motivation.

From the above-mentioned findings it is evident that teachers’ perceptions of their mindsets
and their motivation to teach mathematics differ from their enacted mindsets and motivation
in the classroom. A reason why participants view themselves as having a growth mindset
and being intrinsic motivated, but enacting the opposite, could be that there is a mismatch
between the views of teachers about what is expected from them and that of the curriculum
influenced by society. While teachers perceive their role to be developmental, society
expects good performance. Zee and Koomen (2016) acknowledge that there are differences
between the perceptions held within society viewing learner achievement as the ultimate,
and views held by teachers, who regard their practice as effective when learners show
improvement.

**CONCLUSION**

Teachers’ mindset and motivation play a pertinent role in the teaching of mathematics. Teachers
with a fixed mindset are concerned about learners’ ability to do mathematics. They
also motivate learners extrinsically through praise and external rewards. On the other hand,
teachers with a growth mindset focus on the development of learners and motivate them to
become self-directed.

The purpose of this paper was to establish the mindsets and motivation of SP mathematics
teachers. The findings reveal that most participants view themselves as having a growth
mindset and being intrinsic motivated. However, they enacted a fixed mindset in their
mathematics classrooms and mainly rely on extrinsic motivation techniques.

The misalignment between mathematics teachers’ perceived and enacted mindsets and
motivation implies that members of society should be sensitised about the holistic
development of learners, and not only focusing on performance in mathematics, which
should also reflect in the mathematics curriculum. Teachers should be trained on how to convert from having a fixed mindset to developing a growth mindset, which imply that they should explore new ways of continually developing a growth mindset in themselves, but also in their learners. However, to change mindsets and motivation are not easy, but need hard work and much effort.

The study reported in this paper has a few limitations. The sample size of eight SP teachers in four schools was very small and contextualised to a specific area, namely Gauteng. Therefore, the study cannot be generalised to other phases or areas. A further limitation was that teachers were not observed while enacting their mindsets, but the findings were only based on teachers’ perceptions about their mindsets. A recommendation is to expand such a study to larger sample groups and other phases and schools. Also, this study can incorporate more data collection instruments, for example observations and reflection reports, and data can be collected at different points than only once off. A further suggestion for future research is too compare learners’ mindsets with those of their teachers. A study on how to change a fixed mindset to a growth mindset is also recommended.

The key to a growth mindset is to teach the brain to form new connections, of which all teachers are capable. This type of mindset promotes flexible thinking and the realisation that one is capable of anything one put one’s mind to. Teachers with a growth mindset can motivate learners to take responsibility for their own learning and to explore challenging mathematics tasks, which mayly lead to better performance in the subject.

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CORPORATIVE LEARNING AS A TOOL TO DEVELOP CONCEPTUAL AND
PROCEDURAL KNOWLEDGE IN SOLVING ALGEBRAIC EQUATIONS: A CASE
STUDY OF GRADE 11 MATHEMATICS LEARNERS

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ABSTRACT
This study explored Grade 11 Mathematics learners’ conceptual and procedural knowledge in solving algebraic equations using cooperative learning. This qualitative case study was carried out in a classroom setting in which 34 Grade 11 Mathematics learners participated. The data was collected using a round-table discussion and reflective interviews. The study shows that learners learn better when learning in groups than when learning as individuals. Thus, in this article, we argue that cooperative learning can develop conceptual understanding in solving algebraic equations.

Keywords: algebraic equations, conceptual knowledge, cooperative learning, procedural knowledge

INTRODUCTION
The ability of students to use their Mathematics for purposes beyond doing routine examples and passing formal tests and examinations is a matter of worldwide interest. The concern is at the centre of efforts to give impetus to this application in many national contexts as expressed, for example, in Blum and Niss (1991). Algebraic equations and inequalities play an important role in various mathematical topics, including algebra, trigonometry, linear programming and calculus (Bazzini & Tsamir 2004; Kieran 1989). Algebra is the branch of Mathematics that deals with symbolising and generalising numerical relationships and Mathematics structures and operating with those structures. Further, Van de Walle, Karp and Bay-Williams (2016) indicate that algebraic reasoning involves representing, generalising and formulating patterns and regularity in all aspects of Mathematics. According to the Department of Basic Education (DBE 2011), learners in Grade 10 are supposed to solve linear equations, quadratic equations and literal equations (changing the subject of a formula). The Curriculum Assessment and Policy Statement (CAPS) document makes it clear what must be done in in algebraic equations. In our experience, we found that most of the Grade 11 learners are unable to find the subject of the formula, which was supposed to be dealt with in Grade 10. It was this reason that this study sought to explore Grade 11 Mathematics learners’ conceptual and procedural knowledge in solving quadratic (algebraic) equations using cooperative learning. The study was guided by the following questions:

What are learners’ conceptual and procedural knowledge of algebraic equations?
What are learners’ experiences when solving equations through cooperative learning?
What is the effect of cooperative learning on learners’ conceptual and procedural knowledge of solving equations?

WHAT IS CONCEPTUAL AND PROCEDURAL KNOWLEDGE?
Kharatmal (2009) refers to conceptual understanding as an integrated and functional grasp of mathematical ideas. Kilpatrick and Swafford (2002) further give the definition of conceptual understanding as being able to comprehend Mathematics concepts, to perform operations and relate the concepts. In this study, conceptual knowledge was taken as an integrated grasp of mathematical ideas wherein comprehension, operations and relations of abstract or generic ideas are generalised. Furthermore, Van de Walle (2004) explains that conceptual knowledge of Mathematics consists of logical relationships constructed internally and existing in the mind as part of the network of ideas. This is the type of knowledge Piaget (1964) referred to as logico-mathematical knowledge. This is the knowledge made up of relationships between objects, which are not inherent in the objects themselves but is introduced through mental activity. By its very nature, conceptual knowledge is knowledge
that is understood. This is the knowledge, according to Skemp (1976), which produces relational understanding. This kind of knowledge is referred to as “flexible” knowledge (Boaler 1997), that is, knowledge which can be used in a new situation.

On the other hand, procedural knowledge is derived from procedure and knowledge. According to Rittle-Johnson and Schneider (2013), a procedure is a series of steps, or actions, done to accomplish a goal. Knowledge is only an explanation and an assumption but not the final answer for all questions; it will be discarded along with the human process and a new assumption will appear. The knowledge of the procedure is knowing how or the knowledge of the steps, or actions, done to accomplish the goal.

Furthermore, procedural knowledge of Mathematics, according to Van de Walle (2007), is knowledge of rules and procedures that one uses in carrying out routine mathematical tasks and includes the symbolism that is used to represent Mathematics. This is the knowledge produced by lack of connections of mathematical ideas. If mathematical ideas are seen as isolated from each other, the knowledge produced is referred to as “procedural”. Conceptual knowledge and procedural knowledge can be evidenced when learners solve mathematical problems.

CONCEPTUAL AND PROCEDURAL KNOWLEDGE OF ALGEBRAIC EQUATIONS

Panasuk and Beyranevand (2010) state that conceptual knowledge in algebra can be characterised as the ability to recognise the functional relationship between known and unknown, and independent and dependent variables, and to distinguish between and interpret different representations of the algebraic concept. On the other hand, Bulk, Hull and Miles (2013) define the conceptual knowledge of algebra as a comprehension of mathematical concepts, operations and relations. Students demonstrate conceptual knowledge in algebraic equations when they provide evidence that they can recognise, label and generate examples of concepts; as well as use and interrelate models, diagrams, manipulative and varied representations of concepts.

Further, learners demonstrate conceptual knowledge by being able to identify and apply principles; know and apply facts and definitions; compare, contrast and integrate related concepts and principles; and recognise, interpret and apply the signs, symbols and terms used to represent concepts (Bulk et al. 2013). The description given by Panasuk and Beyranevand (2010) and Bulk et al. (2013) were used in the paper to provide what should be considered when identifying whether or not a learner has a conceptual knowledge of algebra.

COOPERATIVE LEARNING

Mabrouk (2007) states that cooperative learning is when students are working in teams on an assignment or a project under conditions in which certain criteria are satisfied. Cooperative learning is used as the teaching method in which children work in small groups to help one another learn. Cooperative learning was used as it provided the exact meaning of the intention of the study. Hopkins and Salvin (2008) further indicate that in a cooperative learning classroom, students are expected to help each other, to discuss and argue with each other, to assess each other’s current knowledge, and fill in gaps for individual understanding.

In their work, Kagan (1994) and Al-Yaseen (2014) used different ideas to develop a way of implementing cooperative learning. In their study, Zakaria, Chung Chin and Daud (2010) argue that student-centred approaches, such as cooperative learning, improve Mathematics achievement and attitudes towards Mathematics among students. They therefore suggest that cooperative learning is an effective approach that Mathematics teachers need to incorporate in their teaching.

RESEARCH DESIGN AND METHODOLOGY

In this case study, 34 Grade 11 Mathematics learners from a rural school in the Malokela circuit in Limpopo were engaged in the round-table cooperative learning method. The round-
The round-table method was chosen because learners are given an opportunity to brainstorm, review and practise throughout the sessions. There were 6 learners in groups 1 to group 5 and 7 learners in group 6. According to Kagan (1994), there are three steps in the round-table method. Firstly, the teacher asks a question, which has multiple answers, and then each student writes a response or a portion of a response. Secondly, after writing their response, they pass the paper to the next person. Thirdly, one group member may be asked to share with the whole class what their group has written. Learners were observed during the round-table method, and eventually a sample of learners were interviewed based on their participation on their respective groups. The round-table activity can be done with one piece of paper per group or with one piece of paper per group member.

To capture what exactly transpired in the study, the concepts procedural, conceptual knowledge and cooperative learning were used as the lens to explore learners’ knowledge in solving algebraic equations.

**FINDINGS AND DISCUSSION**

We organised our analysis in terms of themes from literature – manipulative and varied representations; and recognising, interpreting and applying signs – and from the data (communication, confidence and motivation; and comparing, contrasting and integrating related concepts). The first author (JF) conveniently selected Learner 2 from group 1 (L2G1), Learner 18 from group 3 (L18G3) and Learner 37 from Group 6 (L37G6) for interviews. The pseudo-codes L for learner were used, G for group number and JF for the first author.

**Manipulative and varied representation**

During the round-table method, learners were busy organising the algebraic equations by using the basic skills of additive inverse and multiplicative inverse to come up with the letter that they were requested to make the subject of the formula. In this case, learners were engaged in the manipulation and organisation of the variables to come up with different representations of the given algebraic equations. Learners were able to explain the way in which they managed to make the particular letter the subject of the formula (find the value of x). For example, from Figure 1, $10x$ is made by $10$ and $x$ as a product, which means that the factors are $10$ and $x$. To separate $10$ from $x$, learners identified that there is a need to divide or use the multiplicative inverse of $10$ which is $\frac{1}{10}$.

![Figure 1: Example 1 from student work](image)

**RECOGNISE, INTERPRET AND APPLY SIGNS**

Learners were able to recognise the operation signs as $+$, $-$, $\times$ and $\div$, and they recognised the bracket as multiplication in the algebraic equation. The purpose of recognising the operations signs helped learners in applying the signs and how to remember the concepts such as multiplicative inverses and additive inverses. Other learners were able to use the signs differently for the same purpose. Some learners used the idea of the multiplicative
inverse whereas some used the idea of division. Because learners were explaining to each other in their respective groups and the whole class, the idea of multiplicative inverse and division were made clear to others who did not understand the relationship.

JF: What happened to the $4(2x - 9)$ on this step?
L2G1: I removed the bracket by multiplying $4$ with $2x$ to get $8x$ and again $4$ with $9$ to get $36$.
JF: What happened to the minus sign in between $2x$ and $9$? Did it have any effect?
L2G1: Yeah, Meneer, (meaning Mr) $4$ is positive and, eh when it multiplies the minus, the answer is minus. So that is why I got $8x - 36$.
JF: Can you explain what happened on the next step?
L2G1: I grouped like terms. Those with $x$'s are on the left and those without $x$'s are on the right.

Figure 2: Example 2 from student work

From figure 2, it is found that some learners were unable to recognise how to multiply when brackets are having a coefficient number that has a negative sign. The interview helped learners to recognise and multiply the problem. Before the interview, some learners could not see a relationship between the division and multiplication signs on the algebraic equations; especially when the variable has a coefficient; learners were finding it difficult to remove the constant from the variable. The following excerpt is from one learner from a group of learners who were able to identify the operations signs and the purpose of the bracket. However, the learner was not doing well like his or her peers. When asking L13G3 about the results and process, the responses were as follows:

JF: You were silent in your group at the first stages. Can you explain to me why or what happened?
L13G3: Hmm, I did not understand, Meneer (meaning Mr).
JF: Explain to me what your role in the group was.
L13G3: I was also writing and giving eh, the answers to others.

The learner removed the brackets by correctly multiplying the number $4$ with $2x - 9$. In this case, the learner was able to use the bracket correctly and the multiplication was done correctly. When interviewed, the learner was able to explain the process and eventually that helped other group members to see the use of brackets. Again, the learner was able to identify the additive inverse. Though the learner used a language that could not be attributed to the Mathematics language, the process was actually the correct Mathematics process of
using the additive inverse. From the second learner, it emerged that L13G3 was unable to understand the equation itself and the basics skills of identifying the subject, the operations and manipulation. The learner was not going to understand the concept of solving algebraic equations.

COMPARE, CONTRAST AND INTEGRATE CONCEPTS
Learners compared the solutions to each problem in their respective groups and presented their agreed solution to the other groups. Within the groups, learners were contrasting their solutions until they decided on the best solution, which made sense to all. The purpose of each group member to present their group agreed solution was to compare, contrast and integrate concepts with other groups.

The above figures (figure 3(a) and 3(b)) indicate different solutions given by different learners within a group. The learners were circulating their solutions, comparing and contrasting as mentioned earlier on.

COMMUNICATION, CONFIDENCE AND MOTIVATION
It emerged that when the learners were interacting; they were communicating and motivating each other to further engage in solving the problems. Whilst they were communicating and motivated, learners gained the confidence to solve even other problems. In this case, the teacher showed an interest in learners’ opinions. The learners felt that their thoughts or ideas were appreciated. This increased self-esteem and confidence. A confident student is less likely to second guess his answers in tests, and a self-assured student is more likely to speak up in class. Class participation leads to increased learning for the entire class. When asking L37G6 about the results and process, the responses were as follows:

JF: I see that your way of solving the algebraic equations are completely different. Explain how you were able to move towards the ability to solve.
L37G6: In the group, eh, we, were talking to each other. Other learners were showing us the way they are solving the problems and eh, mmm, yeah, I understood, and I was able to show mine and explain how I solved it.

CONCLUSION
In this article, we were guided by three questions: What are learners’ conceptual and procedural knowledge of algebraic equations, what are learners’ experiences when solving equations through cooperative learning? What is the effect of cooperative learning on learners’ conceptual and procedural knowledge of solving equations?
It was found that cooperative learning provided learners with an opportunity to explore different ways and strategies of solving quadratic algebraic equations. Further, it emerged that learners' procedural knowledge of solving algebraic equations was developed. The learners who were unable to follow the procedure for solving algebraic equations were helped by the explanations they got from their peers. The reason could be that learners were able to communicate using their own level of communication or language. The study also found that learners' conceptual and procedural knowledge were stimulated when they were cooperatively engaged. Learners felt very comfortable with the process of cooperative learning to the extent that they were motivated to solve more algebraic equations. The communication amongst themselves, as peers, made them more confident and able to engage positively. Confidence helps learners to tackle even difficult problems with the hope that they could find a solution. Drawing on the findings in the study, we recommend that when cooperative learning is used, there should be enough time, especially with Mathematics concepts that seem difficult for learners, for discussing and exchanging ideas. Further, teachers should use arranged algebraic equations in terms of difficulty in order to explore the various ways in which learners could develop both conceptual and procedural knowledge.

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BASIC THEORY OF EDUCATIONAL NEUROSCIENCE FOR MATHEMATICS
TEACHERS – A REVIEW
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ABSTRACT – This paper is a review of how the knowledge of educational neuroscience by teachers of mathematics and its inclusion in mathematics teacher education curricula can enhance our understanding of how students learn mathematics. It is premised on studies that point to two of the obstacles that teachers of mathematics face, that is we know almost nothing about how people do mathematics and we almost know nothing about how people learn how to do mathematics. Teachers’ understanding and knowledge of what goes on in the brain and mind as learners grapple with mathematical concepts and facts could enhance the way we teach and disseminate mathematical information. Teachers’ knowledge of educational neuroscience will also dispel neuromyths - a presentation of facts with little or no scientific bases about the science of the brain, memory and learning.

Keywords: Educational Neuroscience; memory and learning, mathematics learning, neuromyths

INTRODUCTION
This paper explores the introductory educational neuroscience relevant to teachers of mathematics. It explains the underlying neural functioning principles of mathematics instruction and provides neural explanations of the essence of reviews of previously learnt mathematical content and reinforcement of instructions through assessment such as classroom exercises and homework. There is marked evidence that brain based research is finding its way in the teaching as well as intervention approaches that enhance mathematical knowledge acquisition (Tibke, 2019; Howard-Jones, 2010; Cohen Kadosh, Dowker, Heine, Kaufmann & Kucian, 2013). Development in the interest of the application of neuroscientific discoveries to educational practice go back four decades ago (Sousa 2010). In 1983, Leslie Hurt in her now classic works Human Brain and Human Learning, wrote ‘teaching without awareness of how the brain learns is like designing a glove with no sense of how the hand looks like’ (p.13). This statement implies that teachers’ understanding of how children grapple and understand mathematical concepts is critical in ensuring effective mathematical knowledge acquisition. Almost in the same vain, Ansari (2010:128) posted that I would contend that the most effective way of bringing neuroscience into the classroom is to provide teachers with access to knowledge that neuroscientific studies are yielding. This knowledge will inform teachers’ conceptualization of the learning . . . And therefore their pedagogical approaches. These are very important quotes that point to the rationale of teachers’ knowledge of basic neuroscience. Advocates of educational neuroscience (Verschaffel, Lehtinen & Van Dooren 2016; Sousa 2010, Stern & Schneider, 2010) have however hinted at some of the skepticism that neuroscientists hold about teachers being exposed to neuroscience, however rudimentary it maybe. This paper advances and expose the theories of educational neuroscience, especially the science of learning and memory that are pivotal in teacher education curricula because of the various outlined benefits such knowledge would bring to the teachers. It is believed that findings of cognitive neuroscience can be helpful to educational theory. There are however critical proponents of the move to engage neuroscience together with education being that such ambitions are predominantly influenced by cognitive neuroscientists and less so by educationists and the interactions are unidirectional (Turner 2011). The reasons for this one-sidedness is that neuroimaging research outcomes on mathematical cognition for instance, are less open to critical evaluation by educational scientists (De Smedt, Ansari, Roland, Hannula- Sormunen & Schneider, 2011).

BASIC BRAIN ANATOMY FOR TEACHER
Developments in imaging technology have propelled development in cognitive psychology and neuroscience (Purves, Augustine, Fitzpatrick, Hall, LaMantia & White, 2012). Before then cognitive scientists drew conclusions about brain growth or development by watching
how the subjects acquired certain skills, neuroscientists could only infer about brain functions by looking at case studies from patient traumas, strokes and lesions of haemorrhage. The brain could only be studied in an autopsy. The information collected could only inform neuroscientist about where in the brain structures something happened but not the function of the brain. Machines such as the X-rays only revealed hard tissue such as bones and also damaged health brain cells. The Computerised Axial Tomography CAT or CT scan came into use in the 1970s, it had lower X-rays and was able to show variations in soft body tissues. The major breakthrough in medical diagnosis of the brain came with the use of the Magnet Resonance Imaging in the 1980s. These were great for medical diagnosis of the brain traumas by showing the structures that were affected, but what the scientists needed most was technology that would reveal the function of the brain. The functional Magnet Resonance Imaging (fMRI) was the answer (Purves et al. 2012).

The discovery in the 1970 to 1980 about the brain being made up of various regions that functioned independently formed the basis for explaining why different learners have different learning styles and that began the movement to link pedagogy to neuroscientific discoveries (Sousa, 2010). Educational implications in neuroscience and mathematics attest that teachers of mathematics could benefit from knowledge of brain and its basic circuitry (Sousa, 2010; Verschaffel, Lehtinen & Van Dooren, 2016). The brain is part of the Central Nervous System. There are currently more than 10 trillion known connections between neurons in the human brain that can produce varied behavioural capabilities in a human being (Taylor, 2010, p. 48). That means there is still a lot to learn about the brain. In a learner’s attempt to acquire a mathematics concept, there are several parts of the brain that are called into action. The three main parts of the brain cerebrum, the cerebellum and the brain stem are all in one form or another involved when mathematical information is relayed to the brain (Purves et al. 2012). The cerebrum is divided into two parts the right and left hemispheres. The four lobes, Frontal, Parietal, Temporal and Occipital are part of the cerebrum. Figure 1 indicates the core parts of the brain that a teacher of mathematics should be aware of when providing instruction. The thalamus is the part of the brain that relays information from the sensory organs (eyes, ears, skin, tongue and nose) through the sensory neuron to the cerebral cortex which is responsible for complex thought processing such as mathematical cognition (Purves et al. (2012). The brain communicates with the support of neurons or nerve cells as they are sometimes referred to.

Figure 1: Image of the Brain from Brain Facts: A Primer of the Brain and the Nervous System, p.5. 2008 Society for Neuroscience

THE NEURON DOCTRINE – BACK GROUND KNOWLEDGE FOR MATHEMATICS TEACHERS

The neuron is a cell that is made up of the nucleus, cell body the Selma, dendrites and the axon. The neuron doctrine was expounded by a Spanish neuroanatomist by the name of Santiago Ramon Cajal (1852-1934). He used the Golgi staining technique to individualise the cells and pointed out that cells have each got a separate morphology and not a continuous process or system as was earlier defined by Camillo Gogil an Italian neuroanatomist with the reticular theory that advocated that cells morphology were
continuous. Cajal using Golgi staining method expanded on the structural molecular uniqueness of neurons and their connectivity with other cells via the synapse (Poo, 2011).

Research (Purves et al. 2012) show that most of communication in the brain is transferred from one neuron to the other as an electro chemical impulse called action potential. The action potential is the signal by which cells (neurons) communicate in the body. The brain has 100 billion neuron and no one knows the number of connections between them in the nervous system (Purves et al. 2012). There are two types of cells in the body. Neurons are electrochemical producers and transmitters and support cells such as glia cells that guard and insulate neurons. The signal in the neuron is intra cellular and passes through the axon to the neuron terminal. The electrochemical signal is due to the movement of ions which are as a result of change in potential in the cell membrane called polarisation. The change in the membrane is in response to an external stimuli such as a mathematical input. The signal as an action potential is measured in millivolts. The action potential is sometimes referred to as the propagation of a charge in the cell membrane.

AN ACTION POTENTIAL AS A MATHEMATICAL SIGNAL

When mathematical instruction such as the provision of a concept definition is provided to the learner, the message is relayed through the brain cells as an action potential but not every action potential results in learning (Poo, 2011; Purves et al. 2012). The signal travels through the axon to the nerve end of the pre synaptic cells also known as presynaptic neuron. At the presynaptic cell end the action potential potentiates the release of presynaptic neurotransmitters at the presynaptic region of the neuron cell terminal through vesicles. Vesicles carry the neurotransmitters and if the presynaptic cells are in excitatory mode and the post synaptic cells are also in the excitatory mode (excitatory synapse) the vesicles releases the neurotransmitters as chemical reactions into the region between the transmitting neuron and the receiving postsynaptic neurons called synapse. This results in synaptic polarization or depolarizing of the postsynaptic neuron. If the excitatory neurotransmitters are strong enough to reach the threshold of excitation, then the neuron will fire – an action potential that will relay the mathematical impulse further down the neuron. Through a process called reuptake the empty vesicles without neurotransmitters go back into the cell axon to start the process all over again. Figure 2 provides an illustrative explanation of the action potential at synapse that enables the release of neuron transmitters and attach to the receptors of the post synaptic neuron.

THE CELLULAR BASIS OF MATHEMATICAL COGNITION

Mathematical cognition is the mental process and neurological engagement involved in mathematical knowledge acquisition. Mathematical cognition refers to thinking, understanding and remembering and it is the conscious mental activity conceivable in
achieving aspects of awareness, perception, reasoning and judgement. Mathematical cognition is a transmitted neuronal signal. As a mathematics teacher explains a concept a mathematical signal is sent to the recipient, the learner. The signal causes a depolarisation in the neuron that leads to an action potential which is the signal unit of the reaction. Every significant mathematical explanation causes a depolarisation and an action potential.

The transmission of the mathematical signal to the next cell/neuron is due to the synaptic potential. When a group of synapses or mathematical impulses work together they causes an Excitatory Post Synaptic Potential (EPSP) in the receiving neuron. The information is gathered from different inputs to form the excitatory post synaptic potential in the receiving neuron. The persistence and continuous bombardment of the post synaptic cell with similar mathematical impulses leaves an imprint at the synapse and that is mathematical concept acquisition and memory.

NEUROLOGICAL EXPLANATION TO WHY SOME CHILDREN DO NOT UNDERSTAND MATHEMATICS

In cognitive neuroscience the Hebb’s (1949:136) learning Rule - ‘Cells that fire together wire together’ implied that correlated pre and post synaptic activities cause synapse to strengthen/stabilisation. In explaining mathematical learning neuroscience studies have emphasised the importance of relating mathematical content to what the learners already know, prior knowledge, as that strengthens the new mathematics and how the mathematics concepts would be understood (Howard-Jones, 2010; Tibke 2019). Uncorrelated pre and post synaptic activities cause synapse weakening or even elimination leading to mathematical concepts not being understood or concepts being quite easily forgotten (Poo, 2011). The converse is that when the mathematical stimuli causes an action potential, the synaptic connection is strengthened when Cell A keeps firing Cell B, correlated pre and postsynaptic mathematical impulse causes synaptic stabilisation or strengthen the understanding of the mathematical concepts. The postsynaptic cell is an integrator of all the pre synaptic signals or mathematical impulses and a bundle of uncorrelated mathematical signals will yield uncorrelated mathematical outcomes (Poo, 2011).

THE LONG TERM POTENTIATION (LTP) AND MATHEMATICS COGNITION

Bliss and Lomo (1973) in a now classic paper in most memory and learning studies explained in detail how similar sets of mathematical impulses or neurological stimuli that leads to understanding and memory is traced to the various regions of the hippocampus in brain cortex. In their study on the brain of a rat they discovered that a high frequency stimulation of this region of the cortex a synaptic transmission is enhanced for a prolonged period and this is memory (Bliss & Lomo, 1973). The frequent transmission (persistent mathematical input) induces the cellular changes in the hippocampus which can be explained as the trace of memory of the prolonged experiences of the mathematical impulse. The cellular change at the synapse in the hippocampus creates memory which is an electric long term trace of experience and in this instance mathematical experience causing perceptual learning (Poo, 2011). The LTP explains why in explaining mathematical concepts repeated experiences which are revision, sometimes re-teaching of the concepts and class and homework exercises would be important for memory and understanding. The cellular change at the synapse cause the perceptual learning over a longer period of time - memory. Long term memory get encoded in all areas of the cortex.

HOW RELATED MATHEMATICS CONCEPTS ARE EXPLAINED AS INDUCING LTP - INPUT SPECIFICITY

LTP has a property that is input specific (Poo, 2011; Bears et Al. 2001) and this provides further explanations to mathematical knowledge acquisition and cognition. The studies (Bears et al. 2001) explain that if the hippocampus neuron dendrite receives input from two different sources, the side which is highly stimulated (100 Hz/sec) would produce the synaptic amplitude of the EPSP to be higher and lasts longer (memory). The other side of the dendrite will not be potentiated. This is a synaptic modification due to a correlated firing of
cell A and B according to Hebb (Poo, 2011) and only the side of the dendrite that was related to the input get potentiated. The action potential will not occur at the other side of the dendrite where the input is not correlated to the neuron. Only connection between two specifically correlated neurons will be potentiated. LTP is further defined as an increase in the amplitude of the Excitatory Postsynaptic Potential and this leads to neurons in the hippocampus to exhibit long term potentiation (LTP), the cellular molecular basis for memory.

Long Term Potentiation (LTP) due to Associativity

One of the property of LTP is due to neuron’s association with similar input. Poo (2011) explains that if we have two neurons one with a weaker input and another with a stronger input and if the one with a weaker input is stimulated the Excitatory Post Synaptic Potential (EPSP) or current, which is a measure of synaptic strength, an excitatory synapse will not be potentiated and therefore will not produce LTP. The synaptic amplitude of EPSP remains the same as can be seen in figure 4.

![Figure 4: Excitation of weaker mathematical input does not affect EPSP](image)

If the stronger input is stimulated with a high frequency, the post synaptic cells activated will be able to potentiate and activate the LTP as shown in figure 5.

![Figure 5: High frequency on a Strong mathematics input stimulated an action potential - high EPSP](image)

However if the weak input is associated with the stronger input by administering a strong frequency at the same time the weak input is potentiated and the LTD is stimulated in both inputs and the synaptic amplitude of EPSP goes up in both inputs.

![Figure 6: Weak mathematical input strengthened by correlated stimuli associated with stronger input](image)

The descriptions here are critical to mathematical explanations where associativity of mathematical concepts with other related concepts is critical to conceptual understanding. For instance when explaining mathematical concepts it makes sense to relate theorems in circle geometry to properties of a circle and it explains why lack of the latter leads to
difficulties in conceptualising the former. These changes at molecular level are due to synaptic plasticity of the brain and allow for learning and memory.

**THE ESSENCE OF INTERCONNECTIVITY OF INPUT - mathematical signal**

Input such as a mathematical signal is strengthened when it is connected and relevant, hence when mathematics is being taught research (Stein at al 2006; Schoenfeld 2014) show that mathematical information should be related to what the learners know. Neurologically, synapses are strengthened by correlated activities (Cell that fire together wire together) and that perceptual memory of sensory experience involves the formation of a specific group of interconnected cells (Cell assembly) (Poo, 2011; Bear et al. 2001). Mathematical input should therefore point to information that is related, topical and targeted at specific learning outcome. During mathematical explanations – input is targeted at a specific topic with examples, illustrations, class exercises and homework the learner develops strengthened LTP, the connections between the cells is strengthened and this is perceptual learning. There is therefore neurological evidence that understanding mathematics is a result of repeated association of concepts with previously learnt work or previous similar mathematical stimuli. Some synapses are strengthen and others are weakened by experience, the more the experiences/synapses the stronger the memory and learning.

In explaining the mathematical cognition, the input of mathematics concepts will activate specific areas of the cortex respond and stored in one area. This means that the reaction or the synaptic potentiation of neurons are specific to mathematical input and input on the other side of the same dendrite that is not mathematical such as history or language will not potentate the neuron. Only specific synapses that are mathematical will modify that area of the hippocampus – different sites for different inputs. Dehaene (2011) research on the concept of ‘number sense’ - the symbolic representation of quantity as an important foundation for mathematics and laying in specific areas of the cortex. Cantlon et al. (2006) used functional magnetic resonance imaging (fMRI), a neuroimaging technique, with adults and children to examine whether there is an early-developing neural basis for abstract numerical processing and area known as the intraparietal sulcus (IPS) was identified as corresponding to the processing of numbers.

Hussain (2012, p.8) expounds that the information relevant to educational psychologists is that some learners are characterised by specific difficulties understanding number concepts, lacking a sense of number and quantity, and have problems learning number facts and procedures, and such skills have been linked to the developing brain’. Critical here, especially to teachers at elementary school is that children’s brains at this stage are still at their developmental stage and lack of effective mathematical cognition leads to dyscalculia. This is a condition that affects the ability to acquire arithmetical skills. Dyscalculia learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers and have problems learning number facts and procedures (Hussain, 2012, p.8). Studies such as that of Wilson et al. (2001) have used current discoveries in neuroscience to develop computerised educational interventions for learners with dyscalculia. Hussain (2012) points out further that these studies used personalised instructions on the concept of number sense, for instance, to evaluate learners’ performance and relate it to the difficulty of the tasks provided. Temple et al. (2003) asserts that mathematical stimuli that addresses learners’ conceptual enhancement and mathematical performance have neural link and is shown by an increase in brain activity in areas that were originally under activated.

**CONCLUSION**

This paper provided the introductory neuroscience literature envisaged to be essential for mathematics teachers as well as provided neuronal explanations to what causes conceptual knowledge acquisition and how that can be reinforced. There is therefore neurological evidence that understanding mathematics is a result of repeated association of concepts with previously learnt work. In order for learner to understand and consolidate conceptualisation of mathematical concepts frequency of exposure to mathematical concepts has a better
effect on memory than length of the exposure. Repetition through revision exercises, class work and homework and summary of covered content creates LTP because there is reinforcement of the synapses that allow the mathematical information to be retrieved. This type of knowledge is critical for teacher as it reinforces their knowledge of the essence of revision, prior knowledge and constant reinforcement of the instructions with innovative and cognitively appealing teaching aids, illustrations and information. Cognitive dissonance is created when teaching is boring, uncoordinated and superficial, the brain can block the information leading to un-potentiated signals and low or no memory of the mathematics being transmitted.

REFERENCES


IMPLEMENTING PBL IN A FOUNDATION PROGRAMME MATHEMATICS CLASSROOM: RELEVANCE OF PROBLEMS EXAMPLES
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ABSTRACT: This paper attempts to address the question of relevance of mathematical problems that characterised a problem-based learning (PBL) approach in a foundation programme (FP) mathematics classroom. Lebow’s (1993) criteria were used to conduct a content analysis of the types of mathematics problems privileged in the FP’s classes. The constructivist theory of learning as proposed by von Glasersfeld (1995), Vygotsky (1978) and Freudenthal’s (2000) Realistic Mathematics Education (RME) approach are also invoked to critique the design of the problem tasks. The findings suggest that, to greater or lesser extent, the purposefully selected examples fulfil the requirements of the conceptual frameworks outlined by being problem-centred, learner-centred, real-life oriented, context-bound, open-ended, amenable to multiple solution strategies, collaborative and relatively complex or even messy to the learners, and thus encouraging critical, metacognitive reflexivity and out-of-the-box thinking. The pedagogy contrasts, somewhat, with the teacher-centred traditional lecture methods frequently experienced in high school.

Key words: problem-based learning, RME, second chance learners, foundation programme, educationally disadvantaged.

INTRODUCTION
Considerable research has been carried out on the role that a problem-based learning (PBL) approach can potentially play in supporting collaborative learner-centred pedagogy in various disciplines, different educational levels and in a variety of contexts (Savery, 2006). In PBL students working in collaborative groups learn by resolving complex, realistic problems under the guidance of educators (Allen, 2011). Such collaborative learning can have a positive effect on student understanding of mathematics concepts, problem solving skills, academic achievement and affect (e.g. Abdullah et al., 2010; Fatade et al., 2013; Karatas & Baki, 2013; Padmavathy, 2013). However, very limited research has occurred in higher education foundation programme contexts about the nature of mathematics problems that fosters positive learning outcomes. For the purposes of this study, a foundation programme (FP) is considered to be a post school bridging programme that provides a second chance to students from educationally disadvantaged backgrounds for them to improve their National Senior Certificate (NSC) results in mathematics and science in order to access higher education studies in science, technology, engineering and mathematics (STEM) programmes. In a sense, such a programme acknowledges upfront the existence of an articulation gap between school and university mathematics more critically so among learners from historically disadvantaged population groups in under-resourced, non- or low fee-paying schools. A historically advantaged university (HAU), in South Africa, offers a highly selective mathematics (and science) foundation programme to support students who passed their matric, and therefore have the potential, but narrowly missed the cut-off points in the gateway subjects for them to be admitted into STEM programmes. This intervention programme was part of the university’s broad strategy to deconstruct and redress imbalances of the past and to become more inclusive in student demographic profile. It was therefore an important lever of the university’s self-transformation agenda.

The central role played by mathematics (and science) in a country’s economic development is evident in the designation of these subjects by the World Economic Forum (WEF) as efficiency enhancers of global knowledge-based economies (Schwab, 2016). This designation has brought the quality of the teaching and learning of these gateway subjects into sharp focus worldwide. This scrutiny evinces the importance increasingly attached to country rankings in international benchmark tests such as the Programme for International Student Assessment (PISA), the Trends in Mathematics and Science Study (TIMSS) and, more regionally, the Southern and East African Consortium for Monitoring Educational Quality (SACMEQ). WEF’s global competitiveness reports claim to be the biggest ever
global school rankings of 76 countries based on test scores in maths and science derived from PISA, TIMSS and TIERCE (for Latin America) (Coughlan, 2015). The PBL approach was adopted as the signature pedagogy for the foundation programme not just to improve the NSC marks but also to equip students with academic literacy skills, critical thinking skills and study ethos necessary for epistemological access with success in higher education (Morrow, 2009). This paper focuses on the mathematics classroom component of the foundation programme.

THEORETICAL BACKGROUND

PBL is an enquiry-based, constructivist approach to curriculum and instruction that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop viable solutions to defined problems (Savery, 2006). Barrows (1992) concurs that PBL is one of the best exemplars for a constructivist-learning environment. Constructivism on the other hand is a philosophical view on how we come to understand or know. It has three primary propositions. Firstly, it proposes that understanding occurs in our interactions with the environment. That is, knowledge is actively constructed by the individual and knowing is an adaptive process which organises the individual’s experiential world (Karagiorgi & Symeou, 2005, p. 17). Secondly, cognitive conflict is the stimulus for learning and determines the organisation and nature of what is learned through the Piagetian equilibration processes of accommodation and assimilation. (Also typical of messy, non-routine problems encountered in mathematical modelling). Thirdly, cognitive knowledge evolves through social negotiation and through the evaluation of the viability of individual understandings. That is, other people are the greatest source of alternative views to challenge our currently held views (von Glasersfeld, 1995). Vygotsky (1978) uses the metaphor of bridging the Zone of Proximal Development (ZPD) where individual students have the opportunity to move across from the current level/form of understanding to a new level/form of comprehension with the scaffolding of their own effort and prior understandings or those of more knowledgeable others.

Lebow (1993) identifies eight constructivist principles that resonate with a PBL approach: 1) linking all learning activities to a problem or task; 2) supporting learners in taking responsibility for the overall problem or task; 3) designing of authentic tasks in which learners can engage in mathematical activities where the cognitive demands are consistent with the way a mathematician would work; 4) designing the tasks and learning to reflect the complexity of the learners’ environment enabling some form of cognitive apprenticeship; 5) giving learners the ownership of the problem solving process and shifting the educator’s role to that of facilitating learners’ thinking; 6) designing a learning environment to support and challenge the learners to become effective thinkers and workers; 7) encouraging the testing of alternative views and contexts to reinforce knowledge as socially distributed in collaborative learning communities; and 8) encouraging and supporting reflection on the learning process and content.

RESEARCH METHODOLOGY

The purpose of this paper was to gain an understanding of the nature of mathematics PBL problems used in a foundation programme. The following research question guided the study: What was the relevance of problem tasks in the implementation of PBL in the FP mathematics classroom? To answer the research question the researcher adopted a conceptual approach in which qualitative content analysis of selected tasks was conducted to gain insight into the nature of problem tasks presented. Two exemplar problems were selected for analysis, one at the beginning of the academic year and another towards the end of the academic year.
RESULTS

Problem 1: The Security Guard problem

After the main introduction of the PBL ground rules students were immediately divided into groups of five to work on an Amazing Race problem, a map reading problem requiring collaborative work to follow given directions until they find the hidden treasure. See Figure 1.

The problem could be analysed in terms of Lebow’s (1993) criteria of PBL as follows:

a) Linking all learning activities to a problem: the introductory problem was only a beginning of a long journey of the FP year. All learning activities for the first day were linked to the problem task. In that regard Criterion 1 was adequately met.

b) Supporting learners in taking responsibility of the overall problem or task. The learners were divided into small groups of five or six and assigned different roles as outlined in text box 1. Since each learner in a group had a role or responsibility to discharge the fate of the resolution of the problem lay in the hands of the learners.

c) Designing of authentic tasks in which learners can engage in mathematical activities: the fact that security patrols were a common occurrence in the urban set up made the problem authentic, though somewhat distantly, given that the precincts of the education building were not as heavily patrolled by security guards as the problem might imply at first glance. It was therefore a realistic problem though not identical to the real life conditions at the site of learning. Cognitively speaking the demands of the tasks were challenging enough to engender meaningful intellectual and mathematical engagement with the problem. That Andringa Street, Crozier Road and Merriman Avenue were well known streets around the Education Building added to the experience of problem authenticity.

d) Designing tasks that reflect the complexity of the learner’s environment enabling some form of cognitive apprenticeship: The absence of reasons for securing the street between 08.00 and 09.00 rendered the problem less realistic on paper (i.e. contrived) but more open-ended, open to multiple-interpretation and multiple solutions, and therefore cognitively complex enough. That the distances to be covered, and the walking speeds of the guards were not given further opened up the problem to multiple solution strategies and a myriad of assumptions to be drawn up in the solution process.

e) Giving learners the ownership of the problem solving process and shifting the educator’s role to that of facilitating learners’ thinking: That the problem was to be solved in groups where members had designated roles to play placed the responsibility of the problem...
solution process in the hands of the learners. The teacher’s role was of facilitating rather than directing learners’ thinking. The students would only come back for clarification of the task rubric and left to chart their own path group by group.

f) Designing a learning environment to support and challenge the learners to become effective thinkers and workers: the ethos of respecting everyone’s contribution to the problem solution was emphasised to enable all learners to feel comfortable to contribute and be prepared to critique or be critiqued by others, without taking offence. Although this was not self-evident in the task itself it was part of the classroom culture of effectively reaching a solution to the problem as a team.

g) Encouraging the testing of alternative views and contexts to reinforce knowledge as socially distributed in collaborative learning communities: That there were no specific measurements given a priori in the task opened up a dialogical space for learners to make conjectures and test them in the public opinion of other group members. Those other group members would be equally entitled to proffer and defend their own (alternative) views in the same collaborative learning space.

h) Encouraging and supporting reflection on the learning process and content: Students were encouraged to come up with solutions by means of group consensus, which can only emerge in a context of individual and collaborative self-reflection. That there were no pre-set answers in the ‘messy’ problem task enabled learners to reach consensus without expecting the teacher to be the final arbiter, save their own justifications.

Problem 2: The Research Project Problem

In the latter half of the academic year students were assigned a group research project to complete over a six-week period culminating in a research project report and PowerPoint presentations. Within a group, students had to rotate roles introduced at the beginning of the year, this time with a lot more experience. The problem to be solved was an investigation of factors crucial for predicting academic success at the HAU as shown in Figure 2.

- Your group belongs to a consulting agency that analyses data for different companies. The Rector’s Management Team at the HAU has approached you to help them analyse data that they have collected. They want to know what factors best predict academic success at the University and expect you to write a report and do a PowerPoint presentation on your findings. Use the data and formulate different hypotheses based on the different factors available.
  - Present the data using different forms of representation.
  - Consider the similarities and differences that different representations highlight.
  - Determine which representation reflects the information that you want to convey the best? Only include this representation in your report and PowerPoint presentation.
  - Use your analysis to accept or reject your hypotheses.

Figure 2: Factors predicting academic success at the HAU

The students were required to first write and submit an introductory essay on the uses and/or abuses of statistics, how data were collected and how they would be statistically analysed/represented. To compile the report the students had to obtain recent first year results for STEM related programmes at the university. The guidelines for the group PowerPoint presentation were that the investigators/researchers should draw conclusions based on facts/evidence and not opinions. The students were they required to present their reports in a captivating, creative or engaging manner using computer skills acquired in the programme. The problem could be analysed as follows in terms of Lebow’s (1993) criteria of PBL:
a) Linking all learning activities to a problem: The research project was based on a problem that learners had to work on collaboratively to resolve. All sub-tasks of the project were organised to address the research hypotheses. To that extent Lebow’s first criterion of linking all learning activities to a problem was satisfied.

b) Supporting learners in taking responsibility of the overall problem or task: The group structure that had been introduced at the beginning of the year was used as the modus operandi for resolving the problem. To that end, every learner had a contribution to make towards the realisation of the group’s common goal.

c) Designing of authentic tasks in which learners can engage in mathematical activities: That the data to be analysed pertained to factors pertinent to first year success at the HAU in which the students were enrolled for the bridging programme and into which they would be admitted if they passed connected the problem authentically to the students’ ambitions. Student data to be analysed, for example, included the demographic profiles of the students such as, race and home language of a student. That these issues are often critical sources of friction at the HAU meant that students associated with them intimately as determinants of success that needed confrontation, critique and transformation in the ecology and institutional culture of the HAU. Given that the majority of the students in this programme were historically and educationally disadvantaged the task would make them genuinely and sensitively aware of their vulnerability in the academic socialisation processes of the HAU. In other words, it was a real-world problem they could strongly connect and identify with.

d) Designing tasks that reflect the complexity of the learners’ environment enabling some form of cognitive apprenticeship: The sensitive nature of the demographic and socio-economic factors reflected the complexity of the actual lived experiences of the learners’ environment. This was more so in a country that still bears the scars of a racially divided past and continues to feature prominently as one of most unequal societies of modern times according to the Gini coefficient of income inequality (World Bank, 2007). That made the problem not only complex but messy. That learners were to identify independent and dependent variables from the data by themselves and apply statistical techniques such as correlational analysis to rebut or confirm their hypotheses was cognitively complex enough for the level of curriculum engagement expected. It also allowed students to think critically, analyse and solve complex, real-world problems as suggested by Savery (2006). However, students were not expected to carry out rigorous hypothesis testing which would fall outside the scope of their curriculum. One could therefore argue that they were exposed to quasi or informal hypothesis testing. They were, nevertheless, expected to come up with accurate predictions of academic success at the HAU using predictor linear equations, based on the data to understand the complexity of the academic environment they were aspiring to enter.

e) Giving the learners the ownership of the problem solving process and shifting the educator’s role to that of facilitating learners’ thinking: Once again the collaborative execution of the research project enjoined the students to take ownership for the problem solution strategies. The students were, however, required to return to the facilitators to check if they were on the right track or to obtain advice from time to time. Hence, the role of the lecturers shifted palpably from that of direct instruction traditionally followed at high school to that of facilitating students’ thinking and thereby steering them towards autonomy over the direction and pace of their own learning. This kind of facilitation resonates with the view of PBL as a vehicle for self-regulated learning (Malan, Ndlovu and Engelbrecht, 2014).

f) Designing a learning environment to support and challenge the learners to become effective thinkers and workers: The fact the students were expected to work on their own and at their own pace for a duration of six weeks provided them with the opportunity to trial run different solution paths and justify their veracity to the group. That didactic setting
created opportunities for self-reflective engagement and scientific argumentation typical of effective problem solving and therefore supportive of metacognitive thinking.

g) Encouraging the testing of alternative views and contexts to reinforce knowledge as socially distributed in collaborative learning communities: The quantitative exploration of multiple latent variables as likely to bear on a student’s academic success necessarily compelled students to compare alternative relationships (correlations) between dependent (predictor) and dependent (success) variables. The group ethos was to treat each member’s contribution respectfully and on its merits rather than on preconceived assumptions.

h) Encouraging and supporting reflection on the learning process and content: Through their regular (weekly) meetings, students were encouraged to reflect on their progress as a group about the statistical choices, the effectiveness/fairness of their individual contributions towards the group goal in both qualitative and quantitative terms. Groups would be expected to collectively evaluate (reassess) the comprehensiveness and relevance of their literature review, the relevance and accuracy of data collection, collation and analysis procedures, and the validity of conclusions drawn, to answering the research hypotheses.

DISCUSSION AND CONCLUSION

PBL as an active learning instructional approach is a leading example of learner-centred education in which students co-construct knowledge through productive discourse practices (Hmelo-Silver & Barrows, 2006). Barrows (2000) underscores the fact that PBL is primarily premised on the use of ill-structured problems as a stimulus for learning. The challenge in this paper has been to examine the extent to which problems posed in the FP were constructivist, ill-structured stimuli of learning and amenable to multiple solutions. The findings suggest that, to a greater or lesser extent, the purposefully selected examples satisfy the requirements of the conceptual frameworks outlined by being problem-centred, learner-centred, real-life oriented, context-bound, open-ended, amenable to multiple solution strategies, collaborative and relatively complex or even messy to the learners, and thus encouraging critical, metacognitive/reflective and out-of-the-box thinking. The pedagogy contrasts, somewhat, with the teacher-dependent and teacher-dominated traditional lecture methods frequently experienced by the students in their conventional high school mathematics classrooms.

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WHO IS ACTUALLY DRIVING? A TRANS-THEORETICAL VIEW OF MATHEMATICS ANXIETY

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ABSTRACT – Mathematics anxiety (MA, or maths anxiety, for short) is a phenomenon which, at first glance, seems a simple term, but on closer investigation reveals itself to be a highly complex construct. For this reason, we propose in this paper that a trans-theoretical lens is needed when we look at maths anxiety in high school core maths pupils who are already under considerable pressure for their scholastic level. We integrate cognitive-behavioural theory with positive and social psychology tools, as well as drawing on fields of neuroscience, and STEM (Science, Technology, Engineering and Maths) education within the context of increasingly globalised education, which falls within the so-called 4th Industrial Revolution. We claim that not only pupils with poor maths ability can suffer from MA; average to top pupils can, too. These pupils often fall through the cracks where assessment policies drive pupils too fast but do not teach them to steer. We introduce the motorway model as a metaphor for education systems and propose a policy change that includes cognitive affective self-regulation and Mind-Body Skills strategies (which can be taught). These tools offer solutions alternative to medication, psychotherapy, or extracurricular classes.

Keywords: Mathematics, Maths, Anxiety, Somatic Experiencing®, embodied psychology, positive psychology, mind-body skills, high school.

INTRODUCTION: THE NATURE OF MATHEMATICS ANXIETY

When a child goes through a challenging time in their lives, for whatever reason, one of the first places it becomes visible at school is in their science and mathematics marks. The literature suggests that the individual with maths anxiety may have a deficit in numerical reasoning processes without having a clinical anxiety diagnosis. The individual is described as experiencing this anxious state as debilitating, and out of their control, to the point where it disrupts their ability to solve a maths problem, and lowers their maths achievement grades. Attitudes towards mathematics have also received attention in the literature and are well-described (Hannula, 2002; Zan, Brown, Evans, & Hannula, 2006) but will not be dealt with in this paper. Psychometric literature is also very clear on the global consequences of mathematics anxiety. People who are anxious about mathematics tend to sidestep it as far as possible, evading elective coursework in school and university mathematics. They also avoid career paths that involve mathematics (Ashcroft & Krause, 2007). Mathematics anxiety is a phenomenon which, at first glance, seems a simple term, but on closer investigation reveals itself to be a highly complex construct.

As far back as 1972, Richardson and Suinn (1972) defined maths anxiety as “feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations” (p.551). Sherman and Wither (2003) point out that this assumes mathematical anxiety is a causative agent which impairs mathematical functioning. Rubensten & Tannock (2010) make an important point that maths anxiety as a concept, is “not clearly discussed or scientifically studied”, and is “specific to a maths context and therefore distinct and occurring in the absence of generalised anxiety” (p.2). Elsewhere, maths anxiety is defined as “a state of discomfort occurring in response to situations involving mathematics tasks that are perceived as threatening to self-esteem”. There are many other definitions in the literature but the concept lacks clarity, and in many cases authors try to embed it theoretically in either educational or psychological fields. This position paper makes the point that whilst the term math anxiety is currently accepted and used within realms of mathematics, education, and abnormal psychology, it is often approached from a single viewpoint, eg. from Mathematics- or Psychology- fields, or STEM (Science, technology, engineering and maths) education. We propose that if we are to adequately conceptualize the complex construct of maths anxiety, it would be best to consider an inter-disciplinary approach, viz. integrating the education, and/or mathematics fields, as well as the psychological and neurological disciplines.
Rubinsten and Tannock (2010) note that it is generally accepted in lay circles that maths is stressful. Their 2010 research focus was in the realm of the diagnosis of Developmental Dyscalculia (or DD); which in Psychology is classified as a specific learning disability involving “a deficit in processing numerical information” (Rubinsten & Tannock, 2010, p.2). They argue that from a young age the lack of maths abilities may precede and give rise to maths anxiety, creating a vicious cycle. They claim that maths anxiety is distinguishable from other types of anxiety symptoms and has a direct and damaging effect on underlying cognitive processes as the individual performs a maths task. They found this was especially true for individuals with DD. This would suggest that the individual has a pre-existing numerical processing or reasoning deficit. It makes sense that pupils with DD would be more susceptible to maths anxiety, but it would be important to note that maths anxiety is not only found in subjects with poor maths achievement or ability. As an Educational Psychologist based in a high school, the author has observed that high school pupils in the top 10 percent of Maths achievement (and, by implication, ability) also struggle with maths anxiety, despite excellent grades. Others appear average in terms of marks or ability and have erratic performance in tests or exams while displaying significant anxiety levels which disrupts their functioning in many subjects – which is a more general test anxiety – or specifically, in Maths. Thus, for the purposes of this paper, the focus is specific to high school, core maths, pupils, who are under considerable pressure during a crucial cognitive and socio-emotional developmental stage.

This paper suggests firstly that maths anxiety needs to be considered holistically, across multiple theoretical disciplines, and as a complex construct. Evans, Dougherty, Pollack & Rauch (2006, p.10) confirm that various approaches to maths anxiety should be “neither conflicting nor overlapping: they can be seen as complementary, as different lenses that allow researchers and teachers to assume different points of view, in order better to understand students’ mathematical behaviour.” Secondly, we claim that maths anxiety may also be a function of the current social and educational context, and national assessment policies, and is thus not necessarily a pathology of anatomy or cognitive processing. Maths anxiety may often only gain attention when it is due to a learning disability such as Developmental Dyscalculia, or Dyslexia, and when the pupil’s overall grades are low. Thirdly, we based our ideas in this paper on the assumption that there is a complex inter-relationship, unique to the individual, between the individual’s mind (cognitive thoughts and attitudes, reasoning and logical assessment of numerical problems), their body (in particular, the autonomic nervous system, and especially with respect to the primitive fight, flight, or freeze threat response), their internal psychological emotions (neurologically based in the Limbic brain system, involving mood, affect, disposition), as well as their environment, and past experience.

‘STEERING’ MATHS ANXIETY: KEEPING THE DRIVER IN CONTROL AND ON THE ROAD

It would be helpful, at this point, to consider an analogy of individuals who are “driving” their “vehicle” - referred to by Walker and Walker (2015) as “affective-social self-regulation”, or “steering cognition”. These authors refer to the adolescent’s scholastic “journey” as the ‘educational Motorway.’ Steering cognition is described as the way in which the human brain tends to bias its attention toward some things, yet will ‘tune out’ others, before sifting through past memories and experiences, as well as past patterns of self-representation, before it responds. The analogy of the car is sometimes used to explain steering cognition. As the ‘controls ‘of our mind, this steering cognition regulates the mind’s direction, brakes and gears. Studies have shown that steering cognition is not the same as the ‘engine’ of our mind, sometimes referred to as algorithmic processing, which is responsible for how we process complex calculations (Walker, 2015; Evans 2011). Steering seems to involve a primitive system (autonomic nervous system/ANS) which rapidly integrates memory and perception as well as the associated thoughts and sensations in a given situation, leading to a decision or an action.
Walker (2015) draws on a general theory of the mind called Dual-Mind Theory, which asserts that the brain has two parallel systems for processing data. The first system is fast and intuitive, and works by associative thinking and comes up with approximations that may contain error. He explains that this system can be understood as intuitive and unconscious (Walker, 2015). The second system is thought to be a conscious, slower and effortful system, which works by algorithmic processing to reach conclusions; in other words, the brain will apply a “step by step algorithmic procedure in which it works its way through a series of steps to the right answer” (Stanovich, West & Toplak, 2011; Walker, 2015). Walker explains that the brain will choose the intuitive, rapid processing system (System 1) before the slower trial and error system (System 2), because it takes less effort. In other words, if System 2 can override the System 1 with conscious effort we may be able to alleviate anxiety. If anxiety triggers an ANS stress response, which prioritises survival and rapid response rather than rational algorithmic processing, it is clear that an individual suffering with maths anxiety will not think harder, or more rationally, to solve the maths (or the anxiety) problem, since the primitive, intuitive speed-dial circuit has taken over the steering wheel. In response to the question ‘Does the brain think straight?’ the dual-mind theory answer is: “it can but it often chooses not to” (Walker, 2015, p3.). It seems that with Maths Anxiety, it actually cannot. At least, it cannot rationally self-regulate and resume steering and algorithmic processes, until the primitive ANS is regulated. Pizzie and Kraemer (2018) state that “conceptually, maths anxiety encompasses physiological stress responses, negative thoughts and cognitive appraisals due to past and present experiences with maths, as well as more general attitudes and stereotypes associated with maths, gender, and self-identity as it relates to intelligence and academics (p.2). However, they also add that the experience of maths anxiety is equivalent to other types of anxiety, in terms of autonomic nervous system activation.

Walker and Walker (2016) first coined the idea of the Motorway Model to describe a model of education which, they argue, lies behind the current UK secondary school academic assessment framework. The Motorway Model is based on an ideological belief that the quality of education can be measured by the number of pupils, and their distance travelled down an academic road toward narrowly defined, publicly examined, academic targets (Walker & Walker, 2016). They maintain that this model has driven a culture and pedagogy within UK schools to fulfil these motorway goals. For example, schools have narrowed the educational road by reducing the diversity of styles of pedagogy in the classroom and curricula beyond the classroom. They argue that schools have consequently emphasised certain academic streams and types of national exams as indicators of their excellence. The researchers imply that higher academically performing schools within this assessment framework are likely to exhibit greater Motorway Model characteristics than lower performing schools. In South Africa, the independent/private schools often release their Matric results with statements intended to showcase their excellence, such as boasting of a 100% BD (Bachelor’s degree entrance to a university) pass rate. This implies there is only one route to occupational success post matric and ignores any technical or trade driven qualification. Students in South Africa may feel this is the only way to achieve success, rejecting other, or divergent, routes, to occupational careers.

An affective impact on self-efficacy and self-esteem is readily acknowledged in the literature (Pekrun, Goetz, Perry, Kramer, Hochstadt, & Molfenter, 2004), as is a worrying increase in adolescent mental health challenges, such as generalised anxiety, depression, substance abuse and suicidal behaviours, which Walker and Walker (2016) blame on the high stakes testing pressures caused by the Motorway model of education. If we are to address maths anxiety in the South African classroom, we need to suggest a new approach. As such, our starting point would be a psychoeducational strategy (alongside cognitive affective steering or self-regulation principles) but with a more physiological or ‘embodied’ approach. This would involve teaching skills for self-regulation of the body, (i.e. working out exactly who is driving at the time - or, which system has the wheel?) and then follow up with co-regulation and self-regulation skills, to control the mind and emotions. This proposed intervention would
be well aligned with Walker and Walker’s (2015, 2016) cognitive affective steering analogy, and their motor way model, but would also incorporate Stephen Porges’ theory of polyvagal processing (Porges, 2009), in that we would first help the individuals (using co-regulation initially) to learn to regulate their autonomic nervous systems (ANS) and then we could incorporate cognitive steering or self-regulation strategies involving cognitive-behavioural techniques (CBT) (see also Lautenbach & Randell, 2017; 2018). Porges explains that the primitive brain, or ANS, if it perceives threat, will short circuit the rational neocortex and emotional or limbic neurological systems; i.e. The ANS takes the wheel and drives the car, whilst the executive functions needed for maths problem solving are relegated to passengers at the mercy of the new driver, who is focussed on surviving the threat.

Evans et al. (2006) summarise two different arms of investigation in mathematics education research on affect: ‘mathematics anxiety’, and ‘attitude toward mathematics’ (ATM). Most of these researchers assumed a ‘negative’ relationship between test anxiety and performance: test anxiety inhibits cognitive processes, e.g. recall of prior learning, thereby reducing performance. Others considered test anxiety as being the effect of repeated experiences of poor performance. Evans et al. (2006) cites studies that believed that ATM is related to achievement (good grade) outcomes, and affective outcomes (such as liking mathematics) which depend on the memories and experience of past test situations. Once again there is a link between cognitive theory, affect (positive or negative pre-test baselines or post-test situations) and the physiological autonomic stress response (due to associated past memories and experiences); we need to consider the big picture.

We therefore suggest a complex strategy be applied to addressing this complex construct, whereby we would integrate cognitive-behavioural theories and techniques, with positive and social psychology tools, as well as drawing on fields of neuroscience, and STEM (Science, Technology, Engineering and Maths) education principles. These are seen within the context of the increasingly globalised educational context, which falls within the so-called 4th Industrial Revolution.

WHY DO WE HAND OVER THE STEERING WHEEL?

In the light of the above discussion, it would seem that the handing over of the cognitive steering wheel in tests or exams is primarily linked to the neurophysiology of the stress response. Pizzie and Kraemer (2018) define the construct of maths anxiety as one which works on multiple levels, influencing biological responses, social attitudes including self-identification, and cognitive changes, all of which are consistent with the biopsychosocial model of negative affect. They add that maths anxiety exerts changes on a biological level, such that maths-anxious individuals show “amplified activity in regions of the brain associated with risk and awareness, and decreased neural activity in regions associated with mathematical processing” (Pizzie & Kraemer, 2018, p.2).

Integrated, trans-theoretical approaches are emerging. Wilson (2018) proposes the Structured Image Framework Theory (SIFT) model, which aims to integrate the psychological and neuroscientific concepts of information processing and emotional ANS activation. The below figure shows the SIFT Model for how information is perceived, filtered, evaluated, organized, and remembered. It integrates emotional processing, established personal beliefs, as well as illustrates how the primitive brain structures interact with these, enabling higher executive function and perception processes as well as memory encoding, that “consolidates established belief structures.” These belief structures then “influence future emotional processing, thinking and behavioural patterns, for everyday functioning and survival, if warranted, with trauma” (Wilson, 2018).
TAKING BACK THE STEERING WHEEL – DEALING WITH MATHS ANXIETY

Past solutions for dealing with maths anxiety have followed unidimensional theoretical approaches to the concept, since treatments or programmes reflect the lens through which the Maths Anxiety problem is viewed. Fortunately, current trends in dealing with maths anxiety are not restricted to one framework or theory. Spangenberg (2018) mentions studies from the early nineties which offer some basic options to reduce mathematics anxiety, such as cognitive restructuring tools (cognitive behavioural therapy, or CBT techniques) in combination with relaxation exercises, mathematical games outside the classroom and group counselling. Spangenberg (2018) also refers to a 2018 study where psychodrama was used with significant changes in levels of mathematics anxiety.

Similarly, education theorists Adams and Dove (2016) found that students exposed to flipped classroom approaches had significantly decreased anxiety scores. This makes sense in the light of the literature around 4IR (Schwab, 2017) and 21st century skills (Silva, 2009; Dede, 2009) with modern students who turn to learning from the internet as second nature. Besides the collaborative and practical experiences online, there is still room for more innovative solutions related to maths anxiety. Some 4IR-driven studies are emerging in fields of education and psychology involving the use of virtual reality, or VR, which immerses the pupil in the game or situation at hand (Anderson, Price, Edwards, Obasaju, Schmertz, Zimand, & Calamaras, 2013). This raises exciting possibilities for maths anxiety sufferers – imagine a VR world within which they have maths problems to solve, with VR ‘guides’ to assist with autonomic nervous system responses, (which are tracked in real time by their mobile phone’s haptics) and cognitive self-regulation tools. Evans et al. (2006) note that perhaps the most exciting and integrative research pertinent to maths anxiety is emerging from the fields of 4IR, education tools, and neuroscience. Neuroscientific findings as to the interaction among cognition, metacognition, affect, and maths problem solving, further highlight the interrelationship between the primitive brain, emotions, memory and decision-making processes.

DISCUSSION: WHERE IS THIS CAR GOING?

Walker (2016) raises concerns as to the impact of the Motorway Model on mental health – and calls for policy revision in terms of assessment policies. Long term policy revisions are an essential part of this process – and getting these changes in place feels overwhelming when we consider the nature and density of the educational motorways of the world. This suggests that education departments’ and schools’ policies may need to make top-down changes, if young people are suffering mental health issues as a result of the pressures imposed by these policies. If they don’t consider this, they are simply approaching rising levels of maths anxiety by either medicating young people too readily, or labelling them as ‘having a problem’, which requires remedial or psychological therapy, which are also costly in terms of time, energy and resources, let alone in terms of the impact on an individual’s self-
esteem, and higher education curriculum choices. We also propose in this paper that in order to assist in the immediate situation, a less invasive, and less pathologizing approach to managing maths anxiety in high school students would be integrating existing cognitive theories (such as "self-regulation", "cognitive affective steering"), and psychological strategies (such as cognitive-behavioural therapy techniques), with embodied approaches (such as mind-body skills, mindfulness interventions).

An emerging, integrative, neuropsychological, and somatic (or embodied) approach to therapeutic and educational fields is yielding promising results around 'mind-body skills strategies' and how they assist with anxiety and resilience (Saunders, Tractenberg, Chaterji, Amri, Harazduki, Gordon, & Haramati, 2007). With Yoga breathing exercises (pranayama breathing), for example, people practice controlling the breath, or 'prana', to achieve a calm, focussed state. Research findings are also finding multiple benefits from improved sleep quality to inducing an overall sense of wellbeing, as well as reducing anxiety. As early as 1991, neuroscientists at UCLA found an area of the brain which contains neurons that fire rhythmically with each breath, called the pre-Bötzinger complex (Smith, Ellenberger, Ballanyi, Richter, & Feldman, 1991). Also known as the 'breathing pacemaker' it controls several different rhythms in breath – such as yawns, sighs, or gasps - which are associated with social and emotional signals to the brain (as cited in Kwon, 2017). Psychological and embodied therapies and theories, such as Somatic Experiencing© therapy by Peter Levine (2010), or Bessel van der Kolk (1994), are providing significant relief to trauma and generalised anxiety sufferers. For this reason, it would seem wise to consider that the ANS stress or threat response mechanisms, which associate with limbic system affect and memory to override algorithmic or higher order thinking, need to be the starting point with maths anxiety, too.

In theory, pupils with maths anxiety (which is not a generalised anxiety disorder) would benefit as much as those who are diagnosed with such a disorder. Pupils in high stakes exam situations who struggle with maths concepts, and thus maths anxiety, would equally benefit as much as those who are top achievers, and who are experiencing maths anxiety due to the perceived threat of the testing situation, from mind-body skills strategies. There is room for a wealth of research into education systems, high stakes exam pressures, and mind-body skills strategies teaching (see Lautenbach & Randell, 2017;2018), if we are to address this complex problem holistically.

**A FINAL WORD**

This position paper proposes a trans-theoretical approach to dealing with maths anxiety. South Africa's government and private school systems should also heed the warning signs. If this were a road sign, it would resemble those indicating "high accident zone – proceed with caution." The cost to the mental health future of our country and globally to the youth is significant, when we drive students too fast, without teaching them to "steer". Mind-body skills strategies are key tools towards the teaching of steering skills, as well as to managing maths anxiety (both preventatively and reactively) – It would seem significantly better than medicating our youth to cope within the chaos.

**REFERENCES**


ASSESSMENT OF TERTIARY STUDENTS’ LEARNING OF STATISTICAL MODELLING

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ABSTRACT – In this paper, we report on the learning of statistical modelling in a second-year statistics module through the assessment of a problem that required a Monte Carlo simulation. On the forefront of the 4th industrial revolution is science, technology, engineering and mathematics subjects, where mathematical statistics plays a key role in topics such as machine learning and predictive analysis. Students often find statistical modelling difficult, where obstructions in the modelling process could lead towards a dead-end. For this reason, assessment of learning, for learning and as learning in statistics education seems necessary. General pillars of good assessment practice is considered in this study, as well as guidelines for the development of students’ conceptual understanding of the content, such as, statistical reasoning, statistical thinking and statistical literacy. Therefore, this study was conducted to provide educators with information of student achievement of desired student learning outcomes. Based on an analysis of the reports collected individually and through voluntary group work, descriptive statistics are presented. These results are discussed in relation with assessment measures and provides a basis for teaching and learning statistics.

Keywords: Assessment; Statistics Education; Statistical Modelling; Monte Carlo Simulations; Tertiary Education

INTRODUCTION

The demands of the 4th industrial revolution (4IR) and the adequate preparation of students for these demands is a recent and central topic of discussion at institutions of higher learning, and particularly in South Africa (e.g., Hussin, 2018; Xing & Marwala, 2017,). On the forefront of the 4IR discussion is science, technology, engineering and mathematics subjects (compare Idin, 2018). More specifically, mathematical statistics and particularly statistical modelling plays a key role in 4IR, where topics such as machine learning and predictive analysis, to name just a few, is necessary. Educating students in programming languages to be able to unite man and machine is fast becoming a necessary skill in statistics modules, but also in other science and engineering related fields. Statistics and statistical modelling originates from the subject mathematics and more precisely mathematical modelling, where both students and educators find the latter challenging (compare Blum & Borromeo Ferri, 2009). Garfield and Franklin (2011) argue that the difference between mathematicians and statisticians is related to how they view and assess data analysis. Statisticians view data analysis as a process that involves formulating a scientific question that can be answered with data, followed by designing a plan to collect the data, then collecting and analysing the data with appropriate techniques, and finally interpreting the results as they relate to the original scientific questions.

One such procedure is to educate tertiary statistics students in programming languages and to act as true statisticians by using Monte Carlo simulations (named after the city Monte Carlo in Monaco). This kind of simulation of a real-life problem situation is different from a physical experiment as it performs repeated random sampling of the experiment on a computer program to obtain numerical results.

According to the National Research Council (1989, p. 69) it is important for educators to consider “What is tested is what gets taught. Tests must measure what is most important.” Following this notion, Garfield and Franklin (2011) argue that the three pillars of assessment, namely, cognition, observation and interpretation should carefully be considered in the planning of learning activities and the assessment of such activities. Furthermore, students find the learning of statistics difficult and their attitudinal scores can decrease over time (compare Van Appel & Durandt, 2018). Researchers in statistics education suggested cognitive statistical learning outcomes related to statistical literacy, statistical reasoning and statistical thinking (compare Garfield & Ben-Zvi, 2007).
The broad purpose of this study was to measure statistics students' learning of statistical modelling through the assessment of a planned learning activity based on a Monte Carlo simulation. Furthermore, through achieving the desired learning outcomes, students should become better equipped for the demand of 4IR. The idea in this study is to gather meaningful information about the students' learning of statistical modelling, and to better align teaching and assessments in a second-year statistics course. Formally, the research question is: To what extent have students demonstrated cognitive statistical knowledge (literacy, reasoning and thinking) when attempting the Monte Carlo simulation learning activity in a programming language.

THEORETICAL PERSPECTIVES

In assessing students' statistical learning, educators should consider the foundational pillars of good assessment practice (Pellegrino, Chudowsky & Glaser, 2001), as well as the guidelines for the development of students’ conceptual understanding of the statistical content and the desired learning outcomes (compare Garfield & Ben-Zvi, 2007), and the criteria for suitable learning activities (Garfield & Franklin, 2011). This research initiative was grounded in a pragmatic view (Creswell, 2013) and we carefully considered a combination of the following three theoretical perspectives.

The first perspective relates to the three foundational pillars, namely, cognition, observation, and interpretation, which encompass an “assessment triangle” (Pellegrino et al., 2001). These pillars should ideally form the foundation of all assessment practices. Following this notion, Garfield and Franklin (2011) explained the purpose of assessment is connected to all three pillars and assessment practices should be of learning (more summative oriented), for learning (more formative oriented by providing feedback to students) and as learning (oriented as a combination between the summative and the formative placing the student central between learning and assessment). The latter can gestalt in statistics courses through examples that ask from students to create a unique model in an authentic activity where they have the opportunity to reflect and make sense of their own knowledge throughout the creation process.

The second perspective, widely supported by researchers in statistics education (e.g., Garfield & Franklin, 2011), informed this inquiry regarding the categorisation of cognitive statistical learning outcomes (Garfield & Ben-Zvi, 2007):

i. Statistical literary – understanding and using the basic language and tools of statistics.

ii. Statistical reasoning – reasoning with statistical ideas and making sense of statistical information.

iii. Statistical thinking – recognising the importance of examining and trying to explain variability and knowing where the data came from, as well as connecting data analysis to the larger context of a statistical investigation.

The third theoretical perspective relates to the viewpoint from Garfield and Franklin (2011) that informed the selection of the statistical modelling learning activity in this inquiry, which considers the role of cognition by a set of guiding principles. Some of these principles are: to include real data and real problem context, to include recognising and understanding the concept of variability, to include opportunities to select methods of graphing and analysing data, to maintain a balance between items assessing, understanding probability concepts and understanding statistics concepts, and when is it appropriate to require students to provide interpretations of data analysis as well as justifications for their analyses and conclusions.

As a combination, the abovementioned notions informed this inquiry in the selection of the learning activity, in the specification of the learning outcomes and in the assessment of students’ individual and group activity sheets. More specifically, our intention was to balance procedural proficiency, conceptual understanding and the use of context of a statistical investigation through assessment of the learning activity.

RESEARCH DESIGN AND METHODOLOGY
Participants

This inquiry involved a sample of 118 second-year statistics students studying towards a BSc degree in Mathematical Science or a BSc degree in Actuarial Science at a large public university in Johannesburg. All students enrolled in this module are majoring in the mathematical sciences, passed their first-year mathematics and statistics courses, and performed above average in high school mathematics.

Monte Carlo simulations and the statistical modelling learning activity

A Monte Carlo simulation is widely regarded as a very useful approach in solving complex applications in statistics (e.g., Zickar, 2005). More specifically, Monte Carlo simulations are computer driven simulations of the problem using known prior information or parameters to generate plausible random sample data. Thereafter, the generated data are used to evaluate statistics of interest, for example likelihoods, expected values and variability (compare Mooney, 1997; Paxton et al., 2001; Ross, 2013). In addition, Monte Carlo simulation allows one to visualise the potential outcomes of the experiment, which may aid in better overall decision making. In order to conduct such simulated experiments, students need to be educated in using a computer programming language to analyse and solve real world problems (this is commonly known as Education 4.0). Normal practice for students studying towards a degree in Mathematical Sciences is to expose them early on in their undergraduate statistics module to a programming language – for example, Excel in their first year of study and $R$ in their second year of study.

This statistical modelling learning activity was a simplified real world problem and students were required to follow the steps of a Monte Carlo simulation and compile a short scientific report on their findings. In short, we expected the students to conclude whether the potential reward is worth the risk or not. At this stage of their professional development, statistics students have already received the required exposure to complete the learning activity successfully. Formal exposure to statistical content is through theory lectures (where theoretical content is introduced), tutorial sessions (where theoretical problems are solved) and practical classes (where students are exposed to real world problems and introduced to the programming language $R$). Therefore, the students were expected to solve the learning activity by using the programming language $R$ in which they have already received the appropriate preparation. Figure 1 displays the modelling activity used in this inquiry (Braun & Murdoch, 2007, p. 110) and Figure 2 shows an example solution. Students’ were given the activity during the last week of the module and were given the choice to complete the task individually or in groups (maximum of three learners per group).

Simulate the following simple model of auto insurance claims:

- Claims arise according to a Poisson process at a rate of 100 per year.
- Each claim is a random size following a gamma distribution with shape and rate parameters equal to 2 and 4, respectively. This distribution has a mean of $0.5 \text{ million}$ and a variance of $0.125 \text{ million}^2$.
- The insurance company must pay claims on the day they arise.
- The insurance company earns premiums at a rate of $53 \text{ million}$ per year, spread evenly over the year (i.e. at time $t$ measured in years, the total premium received is $53t$.)

Write R code to do the following:

a) Simulate the times and amounts of all the claims that would occur in one year. Draw a graph of the total amount of money that the insurance company would have through the year, starting from zero: it should increase smoothly with the premiums, and drop at each claim time.

b) Repeat the simulation 1000 times, and estimate the following quantities:

i. The expected minimum and maximum amount of money that the insurance company would have at $t=1$.
ii. The expected final amount of money that the insurance company would have at $t=1$.
iii. Comment on the total amount of money that the insurance company would have
c) Carry out any further calculations to enable you to decide whether this is a good business model or not? State whether you would be interested in investing in this insurance company or not. Give a reason(s) for your answer.

**Example solution**

- The expected minimum and maximum amount of money that the insurance company would have at $t=1$ is -23.04436 and 21.0134 million Rand respectively.
- The expected final amount of money that the insurance company would have at $t=1$ is 3.088 million Rand.
- At many instances, the total money that the insurance company has is negative. This implies that the insurance company will need to have access to some credit or finance facility to be able to settle all claims.

**Example Concluding remarks**

- It is not a good business model, since the probability that the bank balance stays positive throughout the full year is only 7.9%. Therefore, it is very likely that a finance facility would be needed, which would drastically reduce the potential profit, or
- the probability that the portfolio will have a positive balance at year-end is 71.3%. Therefore, I would say it is a good business model.

The example solution (see Figure 2) contains a description of some of the information that was expected in the students’ reports, and therefore was used as a guideline in the assessment process, integrated with the notion form Pellegrino et al. (2001) and Garfield and Franklin (2011). For example, students needed to display an understanding of risk in their concluding remarks. That is, we all have different risk tolerances and students should make the choice of whether the risk is worth the reward or not. This free-response item (at the end of the activity) allowed the students to explain and communicate their understanding.

**STATISTICAL ANALYSIS AND DISCUSSION OF RESULTS**

Student answers from the statistical reports were marked and categorised according to the three proposed categories that originated from the literature framework – statistical literacy, statistical reasoning, and statistical thinking (Garfield & Ben-Zvi, 2007). A fourth category was added based on the guidelines from Garfield and Franklin (2011) as it seemed appropriate for students at second-year level to submit a statistical report that showed the processes followed, suitable graphs with descriptions, and concluding remarks as an interpretation of their findings. The grades were allocated according to the scheme: 0 – poor, 1 – somewhat satisfied, and 2 – satisfied. A mark out of two was awarded for each category. Afterwards, a specialist in the field of mathematics education checked all grades. Table 1 displays the descriptive statistics generated from the 37 group reports received. A holistic view of the findings shows that many students struggled to: (i) understand how to combine all the
information given in the real-life problem to correctly answer the problem on their own; (ii) implement the problem in R; and (iii) construct a neat concise statistical report (report appearance). We expected a better-quality solution from students and were concerned about the students that could not even make sense of the data to start with the first step of the Monte Carlo simulation.

Table 2: Descriptive Statistics

<table>
<thead>
<tr>
<th></th>
<th>Literacy</th>
<th>Reasoning</th>
<th>Thinking</th>
<th>Report appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>1.24</td>
<td>0.70</td>
<td>0.62</td>
<td>0.97</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Mode</strong></td>
<td>2.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>0.86</td>
<td>0.85</td>
<td>0.79</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Kurtosis</strong></td>
<td>-1.48</td>
<td>-1.31</td>
<td>-0.91</td>
<td>-1.41</td>
</tr>
<tr>
<td><strong>Skewness</strong></td>
<td>-0.51</td>
<td>0.63</td>
<td>0.81</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td><strong>Maximum</strong></td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
</tbody>
</table>

From Table 1, the statistical reasoning (M = 0.70), thinking (M = 0.62) and report appearance (M = 0.97) received below satisfactory results on average. More specifically, most individuals/groups received a poor result for their reasoning and thinking, and a somewhat satisfactory result on their report appearance. A crucial point to make is the low quality of the statistical reports – students could not correctly express the statistics and had no idea how to compile or present their findings in a neat and well-structured report. Report writing is a necessary skill for a professional statistician and should require more attention during their formal professional development.

We were also interested in the students’ answers of the free-response item at the end of the activity sheet showing how they displayed and communicated an understanding of risk. The responses of four respondents are shown below:

**Respondent 1:** “We would invest in the insurance company since the amount is dependent on the claim.”

**Respondent 2:** “This could be a good business model because both parties have mutual relationship.”

**Respondent 3:** “Yes, we are interested in investing in this company because even though there are drops in the curve, the curve still increases. Therefore, we will make money on our investment. The biggest loss the company can experience is expected to be R3.03m and the most profit is expected to be R6.08m”.

**Respondent 4:** “No, we will not choose to invest in this company. According to our calculations only 66.98% of the 1000 simulations have positive cash flows by the end of the year. Hence the project is only profitable 66.98% of the time. This is therefore a very high risk company to invest in. Also, the variance from the 1000 simulations was R37.51 million with a standard deviation of R6.12 million. Since the mean is only R3.33 million the standard deviation is much bigger than the mean which indicates very volatile cash flows. Hence, profitability of the investment is very unpredictable.”

Respondents 1 and 2 are both examples of poor responses, as they both provided no meaningful information to answer the problem and show no sign of statistical reasoning or thinking in their responses. Respondent 3, is a somewhat satisfactory response that shows an understandable reasoning in the conclusion, however, the answer is lacking further statistical information (which was alluded to in point (c) of the modelling activity) to construct an improved conclusion. In addition, there was not a strong presence of the risk factor in their
conclusion. Thus, the response is lacking in the statistical thinking category. Respondent 4 is an example of a satisfactory response. More specifically, this respondent clearly highlighted the potential risk by calculating the likelihood of a positive balance and the potential spread of the profit at year-end, showing statistical reasoning and thinking.

CONCLUSION

The broad purpose of this inquiry was to measure statistics students’ learning of statistical modelling through the assessment of a planned learning activity based on a Monte Carlo simulation. Furthermore, through achieving the desired learning outcomes, students could become more prepared for the demand of 4IR. The main idea was to gather meaningful information about the students’ cognitive statistical knowledge, and the evaluation of students’ learning to inform a more integrated and balanced assessment practice versus teaching approach. General pillars of good assessment practice have been considered, as well as guidelines for the development of students’ conceptual understanding of the content, such as statistical reasoning, statistical thinking, and statistical literacy. The research question ‘To what extend have students demonstrated cognitive statistical knowledge (literacy, reasoning and thinking) when attempting the Monte Carlo simulation learning activity in using a programming language?’ was answered by interpreting descriptive statistics of the data.

Results revealed some second-year statistics students struggled with organising the data in a statistical modelling learning activity, and more than half of the students performed below average in the statistical reasoning and thinking categories. Although, a few statistical reports were of high quality, the majority lacked important features. With these results, educators in statistics have an improved understanding of students’ misconceptions and required skills and it could lead to a more desirable answer of ‘what evidence do educators need to show student’s understanding’ and ‘will this assessment provide the evidence’?

REFERENCES


ABSTRACT: The ubiquity of digital technologies in life, work and learning are changing the expectations that students have of higher education institutions. In the world of work, the increased use of digital technologies is generating new demands on the curriculum to account for changing skills that required of current graduates. Therefore, higher education institutions need to understand students’ expectations to meet their needs. A survey was conducted among 1937 students at three institutions. The survey instrument comprised closed and open-ended items designed by the UK-based Joint Information Systems Committee (JISC) about their expectations of institutional digital learning environment. The findings indicated that only few students in higher education institutions in Ghana have access to institutional digital resources and devices whenever they needed them. They expect the presence of more digital technology in the learning environment and at the course level. Further, they expect lecturers to teach them the digital skills needed for the workplace. We therefore suggest the expression of employability skills in context of the subject disciplines.

Keywords: digital experiences, digital expectations, digital device, higher education institutions, digital resources

INTRODUCTION

As a consequence of broadened access to digital devices, students entering higher education increasingly do so with more digital capabilities than their predecessors. Through the internet, many students have acquired digital tools and capabilities, which they transfer to their studies over time. These digitally confident students are highly focused on the tasks of study choosing appropriate tools to practice, research and develop on workplace skills using both personal and academic systems. They therefore require basic access to digital services and devices in their institution. Higher education institutions across the world are therefore leveraging these opportunities to enhance students’ digital experiences by improving the institutional digital infrastructure for digital skills development (Alexander, Adams Becker & Cummins, 2017).

Even though policies exist for digital integration in higher education institutions in Ghana to develop students’ digital skills little is known about what the students’ experiences are for the university digital provision as well as their digital expectations for the digital environment in the Ghanaian context. Recent study focused on the students’ experiences with specific aspect on digital skills development in context of the subject discipline, experiences of VLEs on course and students’ value and difficulties of learning with digital technologies (Armah & Westhuizen, 2018).

Developing students’ digital capabilities involves extending their digital capabilities from their basic expectations as a benchmark to a level that is expected for a graduate in the discipline (Coldwell-Neilson, 2017). This study seeks to understand from students’ perspective what their experiences are with their institutional digital resources and devices. The study will also explore the students’ expectations for the institutions digital learning environment. By means of descriptive survey, we investigated those experiences and expectations among students in three dual mode higher education institutions in Ghana. Our objective was not to determine the differences in students’ experiences and expectations by mode of study but to survey a large sample of students in order to obtain broader picture of students’ experiences with the institution’s digital resources and devices as well as their expectations. That will allow higher education institutions in Ghana to better prepare students in terms of digital skills for the digital workplace.

RELATED LITERATURE

Enhancing students’ digital experiences cannot be realized without providing access to digital technologies. Access to digital technologies is key to the development of digital capabilities
According to Beetham and Sharpe (2010) students’ experiences with technology begins from access to technology and functional skills to higher level capabilities. HEIs institutions therefore need to make investment by 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 now requires more of digital skills (Raja & Christiaensen, 2017).


According to Gorard, See and Davies (2012) expectations involves what an individual believe will occur in the future. This can be a behaviour, an outcome or an event (Khattab, 2015).

Mickelson (1990), defines students expectations are tangible values indicating the empirical realities faced by students, i.e. how students think they will perform in reality given their socio-economic background in addition to their past and current academic performance. In this study, students’ digital expectations are defined as those skills and capabilities that students believe they will develop to succeed in academic and career.

"Students expectations for their future influence what they choose to study and the activities they pursue. Factors that shape students’ expectations in the learning environment include the influence of people close to the students, past academic achievement, the relative flexibility of schools’ systems, and the degree of selectivity of higher education.” (OECD, 2017 p. 43).

The students’ expectations, whether intrinsically, or extrinsically motivated by educators or peers, greatly influence their behaviour. These expectations, according to Margaryan, Littlejohn and Volt (2010), are also strongly influenced by their prior experiences. They emphasized that students who have prior experience with technology expect digital technologies to be a part of their higher education studies and would prefer the methods of learning at post-school or work that reflected their learning methods at high school.

Findings from a survey conducted by Walker, Voce and Ahmed (2012) revealed that students’ expectations are driving an improved level of service provision by HEIs, particularly using digital technologies to support application and course selection procedures (see also Duncan-Howell, 2013). A survey report by Universities and Colleges Information Systems Association (UCISA) also indicates that meeting student’ expectations and enhancing access to learning for students is a key factor driving the implementation of technology-enhanced learning in higher education institutions after enhancing quality of learning and teaching in general. The report further highlights that students’ expectations formed the basis for the development of staff digital capabilities (UCISA, 2014).

Before entering higher education, students already have prior expectations about how they will be taught (Beetham & White, 2014; Margaryan, Littlejohn & Volt, 2010; Pleitz, MacDougall, Terry, Buckley, & Campbell, 2015). For instance, they may be aware of and prefer blended learning environments while beginning to experiment with MOOCs (Dahlstrom, Walker & Dziuban, 2013). They therefore expect digital resources to be hosted in institutional virtual learning environment to enable access to them anytime, anywhere from any device (Jewitt, 2012)

In an ECAR report, it was identified that students expect a moderate presence of technology in their course. They prefer freely available course content/open educational resource, e-books, simulations and education games, and e-portfolios in their courses. Other key among the students’ expectations include the need for more and better devices connected to more-pervasive and faster internet, specialized software for their work-based learning support, mobile devices, Personal Computers and Mac machines for academics, and looking to
institutions and instructors for opportunities and encouragement to do so (Dahlstrom, Walker & Dziuban, 2013).

Beetham and Sharpe (2013) argued that despite their high expectations for the HE digital environment students are essentially uncertain about the technologies they will use for study. Some have unrealistic expectation for the digital environment. They are also unclear about how to legitimate use of personal devices, services, networks and practices in academic contexts. They opined that course specific skills especially, do not fully emerge until students have had considerable experience and opportunity to compare their experience with that of other students or the demands of their future career (Beetham & White, 2014). It is therefore important that HEIs make the students aware of the digital skills important in their chosen career and provide avenue for them to develop those skills (Newman & Beetham, 2017). It is also important for students to understand and demonstrate the way in which their knowledge and competencies are being developed to build on them and apply them in different situations.

**METHODOLOGY:**

We investigated students’ expectations of the higher education digital learning environment in Ghana. The study was guided by two main research questions:

1. What are students’ experiences of universities digital resources and device?
2. What are the students’ expectations of the universities digital learning environment?

The quantitative survey contained items that probed students’ experiences of the digital provision in the universities and their expectations of the learning environment. These items were selected the third dimension of JISC higher education insight survey (2018). Part A of the survey seeks to elicit responses about access to and experiences of institutional digital resource and devices. The response type options were a 3-point Likert scale ranging from ‘Never’, ‘Monthly or more’ and ‘Weekly or more’. In part B, students responded to an open-ended question about their expectations of the higher education digital environment.

Final year undergraduate students and postgraduate students from three dual mode higher education institutions in Ghana participated in the study. We used the census survey method to sample all of the students in the population of 32127 students. Altogether 1937 students participated in the online survey, representing a response rate of 6%. There were 1104 (57%) male and 833 (43%) female students. Most of the participants, 49.8% were between 15-25 years old, 30.4% were between 26-30 years old, and 19.7% were 31 and older. The students were drawn from different disciplines. Majority of the respondents 30.8% studied a subject in Education, 21.5% studied Business, 9.9% studied Engineering, Psychology 5.4%, Agriculture science 5.1%, Liberal Arts and Humanities 4.5%, Biological and Medical science 4.2%, Physical science 4.2%, Computer Science 2.8%, Legal studies 2.7%, Architecture and Communications and Journalism 2.1% respectively, and Visual and performing Arts 1.3%. Within the group 54% studied fulltime and 46% studied on distance mode. Most of the respondents were Final year undergraduate students (86%), only 14% postgraduate students.

**RESULTS**

Students were asked to choose which institutional digital resources they had access to whenever they needed them. Resources such as reliable Wi-Fi, online course materials, e-books and e-journals, file storage and back-up, computers and printer and students own social media were listed for students to choose all that apply to them. A summary of the results is shown in Figure 1.
The most common resource available to students was ‘Reliable Wi-Fi. Some 49.1% of the students said they have access to reliable Wi-Fi and 49.8% said they have access to their own social media such as Facebook, and twitter via the institutional Wi-Fi. Only 34.2% opined that they have access to online course materials, whilst 21.9% have access to e-books and e-journals and computers and printers respectively. See Figure 1.

The students were also asked to select from five institutional devices; desktop computer, laptop computer, tablet / iPad, smartphone and printer that they use to support their learning. The percentage summary is shown in Figure 2.

The result in Figure 2 shows that institutional desktop computer is the device used mostly by students to support their learning, but only 41.2% of the students said they use desktop computers. This is followed by institutional tablet / iPad, 12.4% (that is distributed to students by the institution). Few students had access to the institution’s laptop computers (2.1%) and smartphones (2%).

Figure 3 shows the results of students’ active use of digital technology on their course.

Figure 3: Students’ experiences with digital technology in subject discipline

![Figure 1: Students’ access to institutional digital resources](image1.png)

![Figure 2: University owned devices used by students to support their learning](image2.png)

![Figure 3: Students’ experiences with digital technology in subject discipline](image3.png)
Figure 3 shows that use of digital to find information online is relatively frequent in higher education institutions in Ghana. A majority of the students opined that they actively use digital technologies to ‘find information online’. However, almost half of the students said they have never created a digital record / portfolio of their learning; 46.5% of the students have never used a polling device or online quiz to give answers in class. Four in ten students have never produced work in digital format other than word / PowerPoint nor used educational game or simulation for learning. Some 30.4% of the students have never worked online with others.

We asked the students about their expectations of the digital teaching and learning. The result was grouped into themes for further analysis. About 987 out of the 1937 students responded to the question, which is approximately 50% of the respondents. Table 1 summarises the results.

### Table 1: Themes comparison and frequencies of students’ response

<table>
<thead>
<tr>
<th>Theme</th>
<th>Students</th>
<th>Sample Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide digital support</td>
<td>3.9%</td>
<td>Lecturers should be ready to give support to students whenever they need help on digital tools and apps</td>
</tr>
<tr>
<td>Provide digital skills needed for the workplace</td>
<td>6.45%</td>
<td>Teach us both theory and practical digital skills we will need at the workplace.</td>
</tr>
<tr>
<td>Presence of technology on course</td>
<td>11.8%</td>
<td>Bring out course activities which will help us in learning computers and applications</td>
</tr>
<tr>
<td>Access to freely available course content</td>
<td>13%</td>
<td>The university should provide students with free digital teaching and online learning resources e.g. recorded lectures, lecture notes, e-books, e-journals</td>
</tr>
<tr>
<td>Access to robust Wi-Fi</td>
<td>29.05%</td>
<td>Provide free access to stable Wi-Fi Connection without limitations</td>
</tr>
<tr>
<td>Access to quality institutional digital devices e.g. computers and printers</td>
<td>35.8%</td>
<td>Provide quality computers and printers and should be more accessible without restrictions</td>
</tr>
</tbody>
</table>

**DISCUSSION AND CONCLUSION**

The study identified that only few of the students in the three universities had access to institutional digital resources such as e-books and e-journals, whenever they needed them. About four in ten students opined that they had access to computers and printers in their institutions, however only few of the students had access to the institutional desktop computers and printers respectively whenever they needed them. The result also revealed that the most frequent digital activity in the institutions is the use of digital technology to ‘find information online’. However, access to reliable Wi-Fi is still a problem for students in the three institutions. Lack of access to reliable Wi-Fi according to Galanek, Gierdowski and Brooks (2018) impedes students right to digital resources such as ‘online course materials’ and ‘e-books and e-journals’ (see also Bolstad, 2015; Beetham, Newman & Knight, 2018).

Analysis of the free response coded and analysed quantitatively, shows clearly that students expect access to quality institutional devices such as desktop computers and printers connected to more pervasive and faster internet as well as access to robust Wi-Fi at their study point on campus. They also expect digital resources to be hosted in VLE environments to ensure uninterruptible access to the resources anytime, anywhere from any device. This finding is in line with earlier findings by Dahlstrom, Walker and Dziuban (2013). Some students mentioned that they expect digital technologies to be part of their learning as used in the workplace that will allow them to enter a workplace and feel confident with the technology used there. However, these expectations are ignored by the three universities (Duncan-Howell 2013; Walker, Voce and Volt, 2010). These findings are in line with earlier findings that suggest that HEIs need to make the students aware of the digital tools and skills
important in subject disciplines as well as provide opportunities for students to develop those skills in their chosen career (Beetham, Newman & Knight, 2018; Beetham & White, 2014; Jewitt, 2012; Pepler & Jeans, 2016).

CONCLUSION

The study sought to understand students’ experiences and expectations of digital resources and devices in the digital learning environment. The purpose was to provide insight into students’ digital expectations of digital in their chosen career. Students would want their lecturers to use technology on their course that will help them to acquire the skills necessary for their future workplace however, their experiences of the digital resources and tools in the three institutions is less and the universities seem to ignore the students expectations. We therefore suggest the expression of industry standard and up-to-date tools and skills in context of the students chosen career. Further investigation needs to consider digital investment aimed at equipping classrooms with digital technologies and e-Learning solutions to unleash a generation of digital natives in Ghana.

REFERENCES


TABLET TOUCHTUTOR®: A 21ST-CENTURY OFFLINE TOOL TO ENHANCE THE SELF-DIRECTED LEARNING OF FET MATHEMATICS LEARNERS

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ABSTRACT:
The comparatively low 58% pass rate of the 2018 grade 12 Mathematics learners, the below average performance in the Trends in International Mathematics and Science Study (TIMSS) and the Annual National Assessments (ANA) indicate several challenges in school Mathematics teaching and learning in South Africa. Reasons for the low performance include the inferior content knowledge levels of some teachers and the lack of self-directed learning (SDL) amongst learners. The use of effective blended learning has also lacked behind, particularly in quintiles 1-3 schools. Using constructivist and cooperative learning environments outside the normal classroom as the theoretical framework and following a quantitative-qualitative methodology, with the aim to support the classroom activities and enhance SDL, the TouchTutor® Mathematics resource package and the Saturday Incubator Support Programme (ISP) were implemented in the Eastern Cape Province in 2018. Selected grades 11 and 12 learners were supported over sixteen (16) alternate Saturdays. With the TouchTutor®’s interactive digital resources installed in Android Tablets, learners had 24/7 offline access to a range of curriculum-aligned support materials during and between ISP sessions. This paper reports the learning impact and ISP experiences of the learners with the TouchTutor® Mathematics package, as readily accessible, enjoyable, motivating, inspiring, actively engaging, thereby enhancing SDL and improving the performance of learners.

Key words: TouchTutor®; techno-blended model; self-directed learning; 24/7 offline access; Incubator Support Programme.

INTRODUCTION

Of all the 2018 National Senior Certificate (NSC) examination school subjects, Mathematics has the second lowest pass rate of 58% after Technical Mathematics with 50.7% (DBE, 2019). The Mathematics pass rate has been below 60% for more than a decade. Only in 2018, since the introduction of Technical Mathematics, has the mathematics pass rate been better than that of any other NSC subject.

The relatively poor Mathematics performance robs South Africa of the required number of learners who proceed to study engineering, actuarial science and other Mathematics requiring qualifications at tertiary institution. The consequences are fewer than required graduates to fill the available positions and shortage of skilled personnel to drive the relevant economic sector(s) to influence the Gross Domestic Product (GDP) of the country positively.

The low Mathematics results point to challenges in Mathematics education throughout the basic education sector in South Africa (SA) (DBE, 2019; Collet & Steyn, 2017). Amongst Mathematics learners, challenges include their lack of interest and self-directed learning (SDL), low confidence, inability to learn at the levels that they are taught at, and significant content knowledge gaps (Olivier, 2016). Amongst teachers, challenges include lack of confidence and skills of many to effectively teach the Mathematics curriculum, and widespread reliance of many on traditional teacher-centered pedagogies (Olivier, 2016; Collet & Steyn, 2017:455). The lack of quality teaching and learning resource materials for the 21st century classrooms is also a contributing factor (Collet & Steyn, 2017:455; NPC, 2012:302; DBE, 2014; Olivier, 2016).

A TouchTutor® Mathematics resource package and Saturday Incubator Support programme (ISP) Model was introduced in some Eastern Cape Province (ECP) secondary schools in 2018 (and before), to address some of the educational challenges. Developed by the Govan Mbeki Mathematics Development Centre (GMMDC) of the Nelson Mandela University (NMU), the TouchTutor® is based on the integrated use of offline and Mathematics

**Background and Problem Statement**

The TouchTutor® resource package for Mathematics CAPS has many components which include innovative support functions. Included is a series of content video lessons with narration based on graphically enhanced PowerPoints with animations. These resources are supplemented by learner workbooks; interactive multiple choice self-assessment tests with scoring and feedback explanations. Sets of examination revision video series based on past national NSC examinations and memoranda are also included (Olivier, 2018).

A CASIO calculator video series with on-screen emulator demonstrations of how to utilise the scientific calculator adds yet another innovative component to support learning. An integrated curriculum aligned language support functionality is also included to allow the users of the TouchTutor® package to access explanations of Mathematical concepts in English and 7 indigenous South African languages at any time (Olivier, 2018). All of the above are supplemented with guidance and information on Science, Technology, Engineering, Art and Mathematics (STEAM) careers and how to gain access to study programmes at institutions of Higher Education and Training (HET) (Olivier, 2018).

Before implementation in clusters of secondary project schools, an agreement of commitment and active participation was signed between the GMMDC, the management of the schools, the selected learners and their parents. The commitment and participation is for a series of sixteen (16) Saturday ISP sessions of five (5) hours each, from 08h00-13h00, from February to September of the project year (Olivier, 2018). Dedicated in-service Mathematics lead teachers who were trained by the GMMDC facilitated the ISP sessions according to a prescribed educational model and structured programme of sessions (Olivier, 2018). During the period, two and a half (2½) hours of each Saturday is spent on structured grades 11 and 12 Mathematics lessons facilitated through the TouchTutor® Mathematics resource package and according to official school pace setters published by the Department of Basic Education (DBE) (Olivier, 2018).

Being mindful of the low pass rate and the challenges of the South African Mathematics education, the introduction and use of the TouchTutor® raised five main questions regarding the learners:

- What is the impact of the use of the TouchTutor® resource and ISP on learners’ SDL regarding,
  - a) motivation to do more Mathematics individually;
  - b) access to the Mathematics resource material;
  - c) mathematical knowledge gained via TouchTutor®;
  - d) level of sharing with fellow learners and level of engagement with Mathematics?

- Which TouchTutor® technologies and/or resources were mostly accessed and/or used by the learners between the Saturday ISP sessions to learn Mathematics?

- What are the possible places where the learners would use the TouchTutor® between the Saturday ISP sessions to learn Mathematics?

- How often would the learners access the Mathematics on the TouchTutor® between the Saturday ISP sessions to learn Mathematics?

- What average time in hours, would the learners spent per week with the TouchTutor® between the Saturday ISP sessions to learn Mathematics?

**THEORETICAL BACKGROUND**

**Theoretical / Conceptual framework**

The theoretical framework for this study was and still is the establishment of rich, exciting and sustainable constructivist learning environments for Mathematics “in socio-economically challenged school environments” of the under-resourced schools (Olivier, 2018). A modern, innovative, exciting and offline tool called the TouchTutor® based on the integrated use of
digital technologies and Mathematics CAPS resources, was used not only to create the learning environments supporting Mathematics teaching and learning, but also enhance self-directed learning.

The TouchTutor® is a comprehensively Mathematics CAPS-aligned digital resource, techno-blended model available to be used via Android Tablets and phones by learners and laptops by teachers to support and develop the understanding and skills of learners (Olivier, 2017). Using offline rather than online technologies, the TouchTutor® is a new paradigm shift from blended learning, to support Mathematics teaching and learning in South Africa and the developing world. The use of the TouchTutor® during and between 16 Saturday ISP sessions to promote and enhance SDL, represents a conceptual framework for the study, that also influences the way Mathematics is taught and supported at the project schools.

LITERATURE REVIEW

Blended learning is a design that integrates different online technologies with the face-to-face teaching and learning approaches (NWU, 2016). The strengths of the integrated approaches "are blended into a unique learning experience", thereby transforming the structure and approach of the teaching and learning practiced in face-face contact classrooms (NWU, 2016). For this reason, many online learning platforms are available to provide constructivist learning environments to both university students and school learners in many countries, particularly in the developed first world (Olivier, 2018). The effective use of blended learning also satisfies the National Curriculum Statement (NCS) Grades R-12's aim number 6 and is therefore an important tool in the fulfilment of the written and intended curriculum in the policy document.

However, lack of human, material and connectivity related resources in the developing countries like South Africa can partly be blamed for the lack of usage and advancement of online technologies. The specific challenges for blended learning in South Africa’s under-resources schools include web-access in terms of service availability and costs involved, technological skills of teachers and security of the Information and Communications Technology (ICT) equipment (Olivier, 2018). Naturally, the challenges become barriers for the integration of ICT support in education if the challenges cannot be overcome and no alternatives to blended learning are sort and/or found.

For the GMMDC, the offline technologies of the TouchTutor® and the Mathematics CAPS aligned interactive digital teaching-learning resource materials became the solution to some of the challenges of online technologies (Olivier, 2016). The TouchTutor® enabled the integration of ICT support in education (Olivier, 2018). However, the TouchTutor®’s use of offline technologies and resource materials represents a Techno-Blended approach rather than a blended approach which always include the use of online materials (Olivier 2018; ). The techno-blended approach is thus the newest strategy of addressing the challenges in Mathematics education.

Teaching Mathematics is challenging for many Mathematics teachers (Botha et al., 2018). However, the incorporation of ICT can lessen the challenges. Mathematics can be made more accessible and meaningful by the integration of the Mathematical concepts’ verbal language with different media (Botha et al., 2018). The different media include amongst others, the still and dynamic media, with dynamic media distinguishable into interactive media of applications and software packages and non-interactive media of animations and videos (Holzinger et al., 2008).

Self-directed learning in Mathematics is an important educational goal (Bolhuis, 2003:327), and a requisite skill for the active, critical and creative thinking and learning promoted by the DBE through the NCS. Knowles (1975) described self-directed learning as a process by which a learner makes an effort, with and/or without the assistance of others, to determine his/her learning needs. Afterwards he/she formulates his/her learning goals, identifies the appropriate resources for his/her learning, before choosing and implementing his/her learning strategies and evaluating his/her learning (Knowles, 1975).
METHODOLOGY

A QUAN-qual survey on the TouchTutor® experience was administered manually to seventy five (75) King Williams Town secondary school learners in 2018. Fifty one (51) grade 11 and twenty four (24) grade 12 Mathematics learners from 18 secondary schools participated in the survey. The learners also gave general comment(s) on their experience of using the TouchTutor® package. These selected learners with Mathematics potential and interest were identified and selected by the GMMDC in collaboration with the Eastern Cape Provincial Department of Education, Sports and Culture. They were also selected based on a standardised pre-test and historic school based results in Mathematics.

Every learner accessed paper-based survey and responded to the five (5) research questions bulleted in 1.1 above. The five (5) sub-questions a) - e) of the first research and survey question were answered by choosing one of the five (5) options of a Likert-scale choice items of “strongly disagree, disagree, neutral, agree and strongly agree”. The choice answers for the second, third, fourth and fifth bulleted research and survey questions were given as indicated in the results of the respective questions in 5.2-5.5 below.

RESULTS

- For reporting the TouchTutor® impact on self-directed learning (SDL), the “agree” and “strongly agree” responses were combined in answering the first research and survey question. This created opportunity to use pseudo-statistics to rate the impact linked to each Likert item.

<table>
<thead>
<tr>
<th>Research sub-questions</th>
<th>% (raw total out/whole)</th>
</tr>
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<tbody>
<tr>
<td>(a) for motivating them to do more school Mathematics on their own (than before);</td>
<td>89.33% (67/75)</td>
</tr>
<tr>
<td>(b) for making school Mathematics more accessible and enjoyable to do</td>
<td>84% (63/75)</td>
</tr>
<tr>
<td>(c) for inspiring them through the personal ownership of and access to the TouchTutor®</td>
<td>92% (69/75)</td>
</tr>
<tr>
<td>and Mathematics resources</td>
<td></td>
</tr>
<tr>
<td>(d) for sharing knowledge with fellow learners much more easier</td>
<td>90.67% (68/75)</td>
</tr>
<tr>
<td>(e) for being more actively involved in Mathematics than ever before</td>
<td>83% (62/75)</td>
</tr>
</tbody>
</table>

- The following percentages of learners reported access to and use of the specified TouchTutor® resources between the Saturday ISP sessions:

<table>
<thead>
<tr>
<th></th>
<th>% (raw total out/whole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>for pdf PowerPoints</td>
<td>83% (62/75)</td>
</tr>
<tr>
<td>for multiple choice tests</td>
<td>75.67% (56/75)</td>
</tr>
<tr>
<td>for pdf past examination papers</td>
<td>53.33% (40/75)</td>
</tr>
<tr>
<td>for video lessons</td>
<td>44% (33/75)</td>
</tr>
<tr>
<td>for calculator videos</td>
<td>33.33% (25/75)</td>
</tr>
</tbody>
</table>

- The TouchTutor® Mathematics resources were used by the given percentages of learners in the follow manner and/or place:

<table>
<thead>
<tr>
<th></th>
<th>% (raw total out/whole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>at home alone</td>
<td>89.33% (67/75)</td>
</tr>
<tr>
<td>at school with friends</td>
<td>66.67% (50/75)</td>
</tr>
<tr>
<td>in the classroom (not Saturday ISP classroom)</td>
<td>49.33% (37/75)</td>
</tr>
<tr>
<td>in public</td>
<td>44% (33/75)</td>
</tr>
<tr>
<td></td>
<td>9.33% (7/75)</td>
</tr>
</tbody>
</table>
The rate of accessing the TouchTutor® Mathematics resources was:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
<th>(No of accesses/Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularly (more than once a week)</td>
<td>52%</td>
<td>(39/75)</td>
</tr>
<tr>
<td>Nearly every day</td>
<td>29.33%</td>
<td>(22/75)</td>
</tr>
<tr>
<td>Now and then</td>
<td>20%</td>
<td>(15/75)</td>
</tr>
<tr>
<td>Seldom</td>
<td>0%</td>
<td>(0/75)</td>
</tr>
<tr>
<td>Never</td>
<td>0%</td>
<td>(0/75)</td>
</tr>
</tbody>
</table>

- The specific number of hours that the TouchTutor® resources were accessed per week by learners was:

<table>
<thead>
<tr>
<th>No of hours per week</th>
<th>% access per week</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2 hours</td>
<td>45.33% (34/75)</td>
</tr>
<tr>
<td>2-3 hours</td>
<td>29.33% (22/75)</td>
</tr>
<tr>
<td>3-4 hours</td>
<td>14.67% (11/75)</td>
</tr>
<tr>
<td>More than 4 hours</td>
<td>9.33% (7/75)</td>
</tr>
<tr>
<td>Less than 1 hour</td>
<td>2.67% (2/75)</td>
</tr>
</tbody>
</table>

DISCUSSION OF RESULTS

The 83-92% of motivation, inspiration, sharing being, active involvement, accessibility and enjoyment around Mathematics is all good for the dreaded subject that is failed more than any other. An excitement and enthusiasm around Mathematics is generally unheard of and needed more and more to improve the performance in the subject.

The access and use of 83% pdf PowerPoints, 75.67% multiple-choice tests and 53.33% past examination papers is clear demonstration of constant effort by the learners to determine their learning needs, formulate learning goals and use the supplied TouchTutor® learning resources as learning strategies and evaluation tool as well.

CONCLUSION

The TouchTutor® Mathematics resource package is an innovative, powerful and relevant 21st century tool to support the SDL of learners, especially outside the normal classroom. Learners were more motivated, more engaged with the curriculum material than ever before. They were more inclined to collaborate with peers and inspired as a result of the introduction of the techno-blended support model that made Mathematics accessible and enjoyable. The accessing and use of different resources at different places between the ISP sessions regularly, on a daily basis, for an average of 1-3 hours per week, is further sign of learners’ constant self-directed learning.

The average final Mathematics marks of both the Grade 11 and the Grade 12 ISP learners also improved between 2017 and 2018. This confirms the great potential of the Tablet & TouchTutor® with the ISP model to result in improved NSC Mathematics results in under-performing public schools in many parts of South Africa. This Techno-blended approach should be considered for use by the DBE in many more schools throughout South Africa in the near future.

REFERENCES


THE CORRELATION BETWEEN GRADE 11 LEARNERS’ FUNCTIONAL UNDERSTANDING OF PROOF AND ARGUMENTATION

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ABSTRACT – The purpose of this study was to determine the association between argumentation ability and multiple indicators of functional understanding of proof (verification; explanation; communication; discovery; and, systematization) after controlling for gender and sociodemographic variables. Guided by the sociocultural theory, data was drawn from the administration of two survey questionnaires to 135 Grade 11 Dinaledi high school learners from ethnically and socioeconomically diverse communities in the eThekwini metropolitan area, South Africa. Logistic regression was used to identify relationships between argumentation ability and functional understanding of proof. Argumentation ability was positively but tenuously associated with verification, explanation, communication, discovery, and systematization after controlling for gender. Whereas the explanatory function of proof exerted the greatest and statistically significant influence on learners’ argumentation ability, the communication function of proof exerted the smallest and statistically insignificant influence on argumentation ability. Findings suggested that functional understanding of proof may enhance learners’ argumentation ability. Explicit instruction on the functions that proof performs in mathematics is recommended.

Keywords: Functional Understanding of Proof; Argumentation; Multiple Regression; Explanatory Function; Gender

INTRODUCTION Attempts to teach proof to high school learners (frequently during short periods of time) have been unsuccessful (Clements & Battista, 1992; Hadas, Hershkowitz, & Schwarz, 2000; Pedemonte, 2007). Given that the ‘failure to teach proofs seems to be universal’ (Hadas, Hershkowitz, & Schwarz, 2000, p. 128), functional understanding of proof and argumentation, activities Edwards (1997) refers to as the “territory before proof”, need to be part of the mathematical activities that precede and support the development of proofs. Along this line, Marrades and Gutiérrez (2000) argue that it is vitally important for both teachers and researchers in the area of proof to know learners’ understanding of functions of mathematical proof in order to understand their attempts to solve proof problems. The general motivation for this study came from the need to measure learners’ understanding of the functions of proof in mathematics and argumentation quality since lack thereof contributes to difficulties with learning proofs meaningfully (e.g., de Villiers, 1990, Healy & Hoyles, 1998). The researcher joins Hsieh, Horng, and Shy (2012) in considering proof in the classroom more broadly ‘as the product of a spectrum of activities starting with exploration, and progressing to the stages of conjecturing, informal explanation, and justification’ (p. 288).

The phrase “functional understanding of proof” is used to refer to the function that proof performs in mathematics. De Villiers’ (1990) model describes five functions that proof performs in mathematics: verification, explanation, communication, discovery, and systematisation. Thus, proving in the mathematical classroom includes not only cognitive functions (explanation and discovery) but also social (verification and communication,) and epistemological ones (systematization). According to Hanna (2000), the explanatory function of proving helps to make mathematics meaningful and understandable. This “enlightening” or illumination function brings argumentation into the arena. Support for this view comes from Hanna’s (2007) statement that “[a]n argument presented with sufficient rigor will enlighten and convince more students, who in turn may convince their peers’ (p. 22).

Of course, it is necessary to be clear about what is meant by argumentation. Although Pedemonte (2007) correctly argues that there is no common definition for the concept of argumentation in the field of mathematics education, the researcher adopted van Eemeren, Grootendorst, Johnson, Plantin, and Willard’s (2013) definition of argumentation that is compatible with classroom contexts, ‘[a]rgumentation is a verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint’ (p. 5). Toulmin’s (2003) model decomposes an argument into six constitutive elements and
describes the relationships between them: claim, data, warrant, backing, rebuttals, and qualifiers. It was useful in analysing learners’ quality of argumentation. Guided by Vygotsky’s (1978) sociocultural theory of learning, this research question was posed: What is the relationship between learners’ functional understanding of proof and their argumentation ability?

**Geometry in South African high schools** The importance of Euclidean geometry education as an integral component of mathematics curriculum was confirmed when it was made compulsory once again in South African high schools in 2011 (Bleeker, Stols, & Van Putten, 2013; Department of Basic Education [DBE], 2011). This reintroduction of proof into the CAPS mathematics curriculum reflected the notion that there is an appreciation of proof as the basis of mathematical knowledge. This notion finds support in Hersh’s (1997) claim that proof is an essential tool for promoting mathematical understanding. However, for many learners, proof is just a ritual without meaning (Ball, Hoyles, Jahnke, & Movshovitz-Hadar, 2002). This perspective is reinforced when learners are required to write proofs according to a certain scheme or solely with symbols. In South Africa, as in most countries, the geometry curriculum includes Euclidean proof and analytical geometry. Whereas Euclidean geometry focuses on space and shape using a system of logical deductions, analytical geometry focuses on space and shape using algebra and a Cartesian coordinate system (Department of Basic Education [DBE], 2011; Uploaders, 2013).

In this study geometry has been taken to be the mathematics of shape and space, which traditionally incorporates but is not limited to Euclidean geometry. This study focused exclusively on Euclidean geometry on the basis that learner performance in this area has been consistently poor compared to the other geometries just mentioned. The South African high school mathematics curriculum, Euclidean geometry is the place where learners should engage in formal deductive reasoning as they do proofs. As previously mentioned, functional understanding of proof, one of the Specific Aims advocated in CAPS for mathematics, is based on van Hiele’s (1986) broad theory of geometric thinking. Specifically, Euclidean proof (formal deduction) starts in Grade 10. In this grade, learners are expected to investigate, make conjectures, and prove the properties of the sides, angles, diagonals and areas of quadrilaterals; namely, kite, parallelogram, rectangle, rhombus, square, and trapezium (Department of Basic Education [DBE], 2011). In addition, they are required not only to know that a single counterexample can disprove a conjecture, but also that numerous specific examples supporting a conjecture do not constitute a general proof. Accordingly, very few will contest the notion that Grade 10 instruction is assumed to have had an impact on learners’ functional understanding of proof in mathematics. Hence, this study investigated this understanding in Grade 11 learners. However, the weakness in CAPS is that there appears to be a lack of explicit content on the functions of proof as well as the historical aspects of proof.

As the researcher argued earlier, it is precisely this absence of instruction on functional understanding of proof that seem to inhibit learners’ ability to construct proofs. By making the functions explicit, the intended curriculum can be realised. Support for this insistence arose out of Idris’ (2006) assertion that since functional understanding of proof is a largely conventional concept, its learning cannot take place without explicit instruction. Needless to say, this is not a suggestion that ability to prove is secondary but an attempt to underscore functional understanding as a prerequisite aspect of constructing Euclidean proof.

**THEORETICAL BACKGROUND**

Mathematics education research has shown that most learners have serious difficulties with constructing proofs (Conner, 2007; de Villiers & Heideman, 2014). Harel and Sowder (1998) locate the cause of learners’ difficulty in the logical aspect of proof construction. Thompson, Senk, and Johnson (2012) argue that some of the most persistent proof-related difficulties identified among learners in secondary school are a consequence of the confusion about the functions of proof in mathematics. Most research studies have focused on proof and proving...
as content of the curriculum to be learnt and taught. For instance, Knuth (2002) investigated teachers’ conceptions of proof, Wu (2006) and Chin and Lin (2009) focused on learning how to read and write proofs, Hanna and Barbreau (2008) investigated ways to learn proof, and Harel and Sowder (2007) investigated the teaching of proof. A relatively small number of studies has discussed the functions of proof in mathematics (for example, de Villiers, 1990; Bell, 1976, & Hanna, 2000).

As far as the researcher could ascertain, only Healy and Hoyles’ (1998) attempts to capture learners’ functional understanding of proof. They conducted a nationwide (England and Wales) survey of 2,459 Grade 10 learners’ functional understanding of proof in mathematics and how those learners constructed logical arguments (proof) in algebra and geometry. In particular, they used an open-ended survey questionnaire on which learners were to write about everything they knew of proof and its functions in mathematics. Further, they investigated the influence of statutory instruction on the nature of proof following suggestions that such instruction could contribute to deeper understanding of the notion of proof itself and thus improve its didactic treatment in the classroom. They found that the function of proof as a means to verify was prevalent. Hanna (1995) posit that learning about the functions of proof in mathematics is of primary importance to mathematicians. In the same vein, the researcher contends that the value of understanding the functions of proof in mathematics needs to be reflected in the mathematics classroom itself.

Very few can readily disagree with the contention that no single explanation accounts for the low scholastic achievement in Euclidean geometry. However, there is scarcity of empirical evidence on the influence of learners’ functional understanding of proof on the quality of argumentation. Knipping (2003) recommends that it would be interesting if the relationship between functions of proof and argumentation structures were examined. Alibert and Thomas (1991) discuss the relationship between functional understanding of proof largely from a theoretical basis rather than conducting a systematic investigation. They believe that learners’ distorted understanding of the functions of proof is a direct consequence of instruction that presents proof as a finished product; an approach that deprives learners of opportunities to be partners in mathematical knowledge construction.

Vygotsky’s (1978) sociocultural theory of learning underpins the study reported herein. In particular, focus in this study was on the theory’s notion of “zone of proximal development (ZPD)” which he describes as the guidance provided to a learner by a more knowledgeable other (teacher, parent, sibling, or peer) towards the attainment of new knowledge. According to Wersch (1985), interpreter of Russian sociocultural psychology, the notion ZPD was introduced as an attempt ‘to deal with two practical problems: the assessment of children’s intellectual abilities and the evaluation of instructional practice’. The rationale for the choice of this notion of ZPD lies in the fact that the three concepts, “learning”, “argumentation”, and “functional understanding of proof” not only have a social character but also that embedded in them is the overall aim of understanding what learners can do to construct proofs as a result of instructional practices that focus on the “territory before proof”. Throughout this study, the term “learning” is used in a broad sense to encompass not only cognitive but also affective (attitudes and beliefs) notions of learners’ mathematical experience (Stylianides & Stylianides, 2018). From a cognitive perspective, the term denotes the social process of appreciating the centrality of proof in mathematics and knowing how to make mathematically acceptable claims and justify them rather than to mean providing answers designed to reflect rehearsed application of procedures and algorithms only. This definition is consistent with Vygotsky’s (1978) sociocultural theory which considers learning as involving scaffolding of a learner by “more knowledgeable others” such as a teachers, parents, older siblings or even peers.

The present study, therefore, expanded on previous research by disaggregating quality of argumentation and functional understanding of proof into their association with a variety of indicators. The hypothesis was that learners who appreciated the functions of proof engage in high quality argumentation. This relationship was tested controlling for gender.
METHODS

Sample design
Data were drawn, at a single point in time, from three schools randomly selected sample of ten Dinaledi schools in ethnically and socioeconomically diverse communities in the urban district of the Ethekwini metropolitan area in September of 2017. The rationale for selecting Dinaledi schools for the investigation was that these schools were monitored by a team that included senior education department officials and individuals with an interest in educational research. Sample characteristics are presented in Table 1. Additional sociodemographic variables were also assessed. School type was defined as “fee paying” and “no fee”. Race was assessed with a single item: “Do you think of yourself as (1) African, (2) White (3) Indian, (4) or (4) Coloured. Respondents were grouped as African or non-African for multivariate analysis. Three levels of socioeconomic status (SES) were based on the highest educational level completed by either parent/guardian of respondents. Where this information was missing (n=13), the school type attended by the respondent was used to infer their SES.

Table 1: Characteristics of the sample: Sociodemographic factors

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Female</th>
<th>Male</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>School type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fee-paying</td>
<td>28</td>
<td>24</td>
<td>52</td>
</tr>
<tr>
<td>No-fee</td>
<td>44</td>
<td>39</td>
<td>83</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>African</td>
<td>44</td>
<td>39</td>
<td>83</td>
</tr>
<tr>
<td>Indian</td>
<td>18</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>Coloured</td>
<td>7</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>46</td>
<td>39</td>
<td>85</td>
</tr>
<tr>
<td>Middle</td>
<td>23</td>
<td>19</td>
<td>42</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
<td>5</td>
<td>8</td>
</tr>
</tbody>
</table>

Measures
The independent variables that were hypothesized as influencing (predicting) the dependent variable were: verification, explanation, communication, discovery, and systematization. Functional understanding of proof was assessed with the Learners’ Functional understanding of Proof (LFUP) scale. Quality of argumentation was assessed with the Argumentation Frame in Euclidean Geometry (AFEG) using the mathematical statement that The interior angles of a triangle sum up to 180°. The duration of the questionnaires was 30 minutes. It consisted of prompts as shown in Figure 1.
Two researchers determined the reliability of the tool using Cohen’s (1968) kappa coefficient (\(\kappa\)). In addition, this coefficient was appropriate to use on the basis that we adopted a multcategory rubric comprising an ordinal scale in which responses were classified into 1 of 5 types of categories. Cohen’s interrater agreements (\(\kappa\)) were: content = .95 and argumentation = .97. As Altman (1991) suggests, these values indicated very good agreement between raters.

**Analysis**

The LFUP questionnaire has 25 Likert scale items that range from 1 (“Strongly disagree”) to 5 (“Strongly agree”). The scores on the LFUP scale were treated as interval level scale which was amenable to parametric statistical analyses. A five-tiered grading scale was used to assess learners’ functional understanding of proof. Mean responses were interpreted according to the following categories: 0–<1.5 (unencultured); 1.5–<2.5 (poorly encultured); 2.5–< 3.5 (hybrid); 3.5–<4.5 (moderately encultured); 4.5–≤5 (extremely encultured). Learners’ quality of argumentation was the dichotomous (binary, i.e., low or high) dependent variable whose values were to be predicted and therefore only contained data coded as 0 or 1. Table 2 describes how the quality of argumentation was assessed. The analysis was performed with the assistance of SPSS v.24 (Statistical Package for the Social Sciences for Windows (SPSS), 2017).

<table>
<thead>
<tr>
<th>Argument</th>
<th>Definition</th>
<th>Code description</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>My statement is that …</td>
<td>A claim (C) is a conclusion put forward publicly for general acceptance (Toulmin, 2003).</td>
<td>No reply; uncodifiable.</td>
<td>Low</td>
</tr>
<tr>
<td>My statement is that …</td>
<td>(Toulmin, 2003).</td>
<td>C (Claim; conclusion)</td>
<td>Low</td>
</tr>
<tr>
<td>My reason is that …</td>
<td>A warrant is ground (G) provided in justifying the claim.</td>
<td>C+G (Providing reason for claim)</td>
<td>Low</td>
</tr>
<tr>
<td>Arguments against my idea might be that …</td>
<td>A rebuttal (R) meant statement that sought to diminish the strength of a conclusion (Pollock, 2001).</td>
<td>C+G+R (Refutation of claim/ground)</td>
<td>High</td>
</tr>
</tbody>
</table>
RESULTS AND DISCUSSION

Attempts to interpret the correlation between functional understanding of proof and argumentation quality were hampered by the possible existence of a third variable that may influence the relationship between the two variables. The researcher used partial correlations technique to statistically control or nullify the effects of gender (Wilson & MacLean, 2011), as the third or secondary variable, on the relationship between the primary variables; namely, functional understanding of proof and argumentation quality. The partialling out of gender was informed by research (e.g., Geary, 1999; Healy & Hoyles, 2000) which suggests that learner performance in mathematics tends to be a function of gender.

Since the zero-order correlations have already been analysed above, the researcher considered the section with the partial correlations in Table 3. In the previous section, the significant relationship between functional understanding of proof and gender seemed to suggest that gender has influence in explaining the understanding-argumentation association. However, the partial correlations section shows that controlling for gender further weakens the strength of the significant relationship between functional understanding of proof and argumentation ability ($r = .214$, $p = .013$). Clearly, controlling for gender was justified given that it was, as shown in Table 3, one secondary variable that seemed to influence the relationship between the two primary variables.

The multiple correlation coefficient between argumentation scores and covariates combined, $R$, was computed. Then, the coefficient of determination ($R^2$) which is the square of the Pearson product moment correlation coefficient, was used to express the proportion of variability in argumentation that can be accounted for by particular functional understanding of proof. According toMuijs' (2004) criteria, this model is of poor fit as it meant that only as low as 6.3 % of the variance in the argumentations scores were explained by the covariates (Table 4).

<p>| Table 3: Assessing the influence of functional understanding of proof on argumentation; controlling for gender |</p>
<table>
<thead>
<tr>
<th>Control Variables</th>
<th>LFUP score</th>
<th>AFEG score</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Correlation</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>133</td>
<td>0</td>
</tr>
<tr>
<td>LFUP score</td>
<td>Correlation</td>
<td>.225</td>
<td>1.000</td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>.009</td>
<td>.</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>133</td>
<td>0</td>
</tr>
<tr>
<td>AFEG score</td>
<td>Correlation</td>
<td>.171</td>
<td>.089</td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>.047</td>
<td>.302</td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>133</td>
<td>133</td>
</tr>
<tr>
<td>Gender</td>
<td>Correlation</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Significance (2-tailed)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>df</td>
<td>132</td>
<td>0</td>
</tr>
</tbody>
</table>

*a Cells contain zero-order (Pearson) correlations.*

The multiple correlation coefficient between argumentation scores and covariates combined, $R$, was computed. Then, the coefficient of determination ($R^2$) which is the square of the Pearson product moment correlation coefficient, was used to express the proportion of variability in argumentation that can be accounted for by particular functional understanding of proof. According to Muijs' (2004) criteria, this model is of poor fit as it meant that only as low as 6.3 % of the variance in the argumentations scores were explained by the covariates (Table 4).

<p>| Table 4: A summary of the $R$, $R$ square and adjusted $R$ square in analysis of LFUP and AFEG |</p>
<table>
<thead>
<tr>
<th>Model</th>
<th>$R$</th>
<th>$R$ Square</th>
<th>Adjusted $R$ Square</th>
<th>Std. Error of the Estimate</th>
<th>Change Statistics</th>
<th>Sig. F Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>.252$^a$</td>
<td>.063</td>
<td>.056</td>
<td>.87517</td>
<td>.063</td>
<td>9.011</td>
</tr>
</tbody>
</table>

*a. Predictors: (Constant), T15*  
*b. Dependent Variable: AFEG score*
Multiple regression was run to tease out which of the functional understanding of proof variables were most closely associated with argumentation quality (Table 5). The beta (β) values in Table 5 provide interesting information about some of these factors with regard to their relative effects on argumentation. First, whereas knowing that proof explains had the strongest positive and statistically significant effect on argumentation where β = .502 and the level of significance, p = .006, knowing both that proof is a means to verify and discover had nonsignificant impact on argumentation. Second, whereas knowing that proof is a means to systematize and communicate mathematical ideas yielded nonsignificant results, the former had a weakest negative effect (β = -.074) and the latter the strongest negative effect (β = – .327). Third, only knowing that proof systematises had a statistically nonsignificant result at .174 (p > .005) effect on argumentation. The interesting conclusion here was that only having an understanding that proof as a means to explain can be used to predict learners' argumentation ability.

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>.001</td>
<td>.569</td>
</tr>
<tr>
<td>Verification</td>
<td>.140</td>
<td>.182</td>
</tr>
<tr>
<td>Explanation</td>
<td>.524</td>
<td>.186</td>
</tr>
<tr>
<td>Communication</td>
<td>-.073</td>
<td>.228</td>
</tr>
<tr>
<td>Discovery</td>
<td>.164</td>
<td>.187</td>
</tr>
<tr>
<td>Systematization</td>
<td>-.266</td>
<td>.195</td>
</tr>
</tbody>
</table>

CONCLUSION
The purpose of this study was to investigate the relationship (if any) between learners’ functional understanding of proof and their argumentation ability. Guided by the sociocultural theory, the basis for the hypothesis was formulated and appropriate data collection and analysis methods were selected. The hypothesis was supported by the empirical evidence in that the correlation between functional understanding of proof and quality of argumentation was, although tenuous, positive and statistically significant. Whereas, relative to each other, the explanatory function of proof exerted the greatest and statistically significant influence on learners’ argumentation ability, the communication function of proof exerted the smallest and statistically insignificant influence on argumentation ability. In other words, the explanatory function of proof was found to be the factor which best predicted learners’ success in argumentation ability. One limitation of this study is that the findings cannot be generalized to the population of Grade 11 learners.

The recommendation that Euclidean geometry curriculum needs to be revamped for the purpose of making functional understanding of proof and argumentation explicit and assessable content has implications for two constituencies. Instructional practices in high schools and methods modules at teacher training institutions need to include these exploratory activities (functional understanding of proof and argumentation) prior to engaging in the final step of formal proof construction. The limitation of the study is that learners’ responses to the questionnaires were not probed. Future research initiatives need to blend close-ended items with open-ended questions to enhance insights into learners’ functional understanding of proof because the results have shown that functional understanding of proof is a significant predictor of the quality of argumentation. Overall, the results of this study are offered as a contribution to the field’s growing understanding of learners’ activities prior to constructing proofs.
REFERENCES


ABSTRACT – Graduate attributes of IT students during a WIL activity in Systems Analysis and Design and Business Management modules were investigated. The graduate attributes considered in the study were communication, teamwork, analysing and investigating, initiative or self-motivation, planning and organising, time management, conflict resolution, self-awareness (e.g. reflective thinking, self-discipline, flexibility, dedication), integrity and stress tolerance. The purpose of an overarching project that started in 2010 at North-West University (NWU) was to enhance the work-readiness and soft skills of IT students by doing practical work in industry. The purpose of the paper is to compare the perspectives on the graduate attributes of students. Both the perspectives of students and managers or employers of companies where students worked during the WIL activity, were investigated. In addition, the paper presents the relationship between students’ perspectives regarding graduate attributes and module marks. Specific experiences of students including skills learnt and personal aspects that need change are presented in the paper. Electronic questionnaires were used to gather data from managers and students after the WIL activities. Results during 2017 and 2018 revealed that the perspectives of managers regarding the graduate attributes communication, initiative or self-motivation, planning and organising, time management and integrity were more positive than the perspectives of students.

Keywords: Graduate attributes, Work-integrated learning (WIL), IT students

INTRODUCTION

The paper focuses on a section of a bigger research project conducted at NWU to investigate the work-readiness and soft skills of second-year IT students during WIL activities. There is a need to align academic content and industry experiences as part of IT education. Since 2010 NWU students in the Systems Analysis and Design and Business Management modules have been doing practical work for between one and three weeks in corporate environments during the winter holidays. Data to determine the experience of IT students during and after the WIL activities has been collected from 2015 to 2018, including students’ level of competency, work-readiness and soft skills. Since 2017 data to determine the experience of managers or employers regarding graduate attributes of students involved in the activity, was also collected. In the paper graduate attributes of IT students participating in a WIL activity were considered. The perspectives of both students and managers of companies where students worked, were investigated.

The following research questions were stated: How do management’s perspectives on the graduate attributes of students differ from students’ own perspectives during WIL? Is there a relationship between students’ perspectives on their own graduate attributes after WIL and module marks for the Systems Analysis and Design or Business Management modules? What are the most important skills learned by students during WIL? What personal aspects that need change did students identify during WIL? The paper is structured as follows: in the following section, a theoretical background of graduate attributes and employability skills is presented, after which the methodology is discussed. Results and the discussion thereof follow in the next section and in the last section, the paper is concluded.

THEORETICAL BACKGROUND

Graduates today need to have expert workplace skills in order to meet the challenges of the current era (Musa, Mufti, Latiff, & Amin, 2012). According to Osmani et al. (2016), technical skills alone are insufficient for IT professionals to be successful. IT professionals need soft interpersonal skills to be able to meet the challenges in the dynamic and complex IT industry (Osmani et al., 2016). The Australian Technology Network (Bowden, Hart, King, Trigwell & Watts, 2000) defined graduate attributes as: “the qualities, skills and understandings a
university community agrees its students would desirably develop during their time at the institution and consequently shape the contribution they are able to make to their profession and as a citizen”. In the NWU strategy document (2016) graduate attributes are described as “personal qualities, and academic, professional and practical knowledge and skills”. A recent publication by Oliver and de St Jorre (2018) focusing on Australian higher education and graduate attributes beyond the year 2020, recommends graduate attributes needed in future to include communication, critical thinking, ethical engagement with communities, teamwork, learning and working independently, problem-solving and information literacy. According to Oliver and de St Jorre (2018) terms to describe graduate attributes are used interchangeably and boundaries between the terms became ‘blurred’ over the past twenty years. In the paper the terms skills, competencies, qualities and abilities refer to graduate attributes. The attributes covered in the questionnaires used for managers and students during the study, closely correspond to the attributes found in recent literature.

To justify the attributes self-awareness and integrity used in the questionnaires of the study, Scoufis (2000) identifies sensitivity to multicultural issues, awareness of ethical issues and civic responsibility to be important qualities that graduates should have. In support of the attributes identified by Scoufis (2000), Nagarajan and Edwards (2014) included attributes such as the ability to work with people from different spheres, (e.g. business, IT, international and interstate sites), communication with people from different cultures and work ethic as being important.

Problem-solving, critical analysis and creative thinking abilities were considered to be important attributes graduates should have (Moalosi, Oladiran, & Uziak, 2012; Scoufis, 2000; Nagarajan & Edwards, 2014; Musa et al., 2012; Saad & Majid, 2014). In the questionnaires the attribute “analysing and investigating” were used.

In support of the attributes initiative or self-motivation, planning and organising, time management and stress tolerance used in the questionnaires, Scoufis (2000) highlights independent initiative while Musa et al. (2012) regard self-motivation and self-management desirable attributes graduates should have. Nagarajan and Edwards (2014) confirm the abilities to develop new skills, adapt to dynamic work requirements and to use technology to manage time, to be important. Saad and Majid (2014) endorse the importance of lifelong learning skills while Moalosi et al. (2012) affirm the ability to plan, organise and prioritise work as being important.

Scoufis (2000), Moalosi et al. (2012), Nagarajan and Edwards (2014), Musa et al. (2012) and Saad and Majid (2014) confirm that the attribute communication used in the questionnaires, is a necessary ability for graduates to have. According to Moalosi et al. (2012) communication includes the abilities to communicate verbally with persons inside and outside the organisation, sell or influence others and create and/or edit a written report. Nagarajan and Edwards (2014) regard formal and informal communication with senior colleagues and people from different cultures part of communication abilities needed in the challenging work environment.

The attributes teamwork and conflict resolution used in the questionnaires are confirmed to be important by Scoufis (2000), Moalosi et al. (2012), Nagarajan and Edwards (2014), Musa et al. (2012) and Saad and Majid (2014). Nagarajan and Edwards (2014) regard using technology, tools and techniques for team interaction, as skills needed by graduates.

The questionnaire used for the study had questions covering the above discussed graduate attributes self-awareness, integrity, analysing and investigating, initiative or self-motivation, planning and organising, time management, stress tolerance, communication, teamwork and conflict resolution.

**METHODOLOGY OR METHOD**

Students were given specific instructions and outcomes to reach during the WIL activity:
INSTRUCTIONS

Students were guided to use own personal networks (family, friends and acquaintances) to identify and approach possible companies. Students were given an assignment in advance to be completed during the WIL. The assignment required the students to report on the business in general, as well as on specific IT-related topics, including software development methodologies, hardware and software used, security aspects and project management approaches used. Students received a letter from the university addressing the manager(s) of the company involved in the WIL. The letter communicated the aim of the WIL, the framework of the assignment and possibilities for the practical time. Appreciation was also expressed to the companies for the value exchange. The two defined questionnaires were developed in Google Forms and the links communicated to managers and students involved. After the completion of the WIL activity, all managers were requested to complete the online questionnaire for managers. After the holidays, students had to submit their assignments. The marks of the assignments counted towards the final participation marks for the Systems Analysis and Design II and Business Management modules. Thereafter, all involved students were asked to complete the online questionnaire for students.

RESEARCH INSTRUMENTS

The students’ questionnaire comprised four sections. Section 1 contained demographic information: type of industry, previous work experience, age and gender. Section 2 contained information regarding work experience during the WIL: main activities, how challenging the work was, how likely the students would be to work for the company involved, the most satisfying aspects of practical work and the least satisfying aspects of practical work. Section 3 contained information regarding personal development and skills competencies (graduate attributes) assessed according to a 4-point Likert-type scale with response categories being poor, fair, good and very good. The following graduate attributes were included: communication, teamwork, commercial awareness, analysing and investigating, initiative or self-motivation, planning and organising, time management, conflict resolution, self-awareness, integrity and stress tolerance. Section 4 contained two qualitative questions on the most important skill learnt and an important personal aspect needing change to promote success in careers.

The managers’ questionnaire comprised three sections. Section 1 contained demographic information: type of industry and size of company. Section 2 contained information regarding the students’ work experience: how challenging it was, would the student’s abilities and skills add value to the company, did the WIL experience improve the student’s employability, will the WIL experience lead to the possibility of full-time job offers from the company. Section 3 contained information regarding the skills and competencies (graduate attributes) of students assessed according to a 4-point Likert-type scale with response categories being poor, fair, good and very good. The same graduate attributes of the students’ questionnaire were included: communication, teamwork, commercial awareness, analysing and investigating, initiative or self-motivation, planning and organising, time management, conflict resolution, self-awareness, integrity and stress tolerance.

RESEARCH POPULATION

The research population for the students’ questionnaire comprised second-year students in IT, BCom, Entrepreneurship and Business Management. The questionnaire was completed by 154 students of which 90 were IT students. The research population for the managers’ questionnaire comprised managers of companies where students worked during WIL. The questionnaire was completed by 183 managers of which 99 were from the IT industry. Participation was voluntary, informed consent was given and ethical clearance was obtained from NWU. Both students’ and managers’ responses are reflected upon in the paper.

STATISTICAL ANALYSIS

Content analysis was performed on the qualitative data from section 4 of the students’ questionnaire. Descriptive and the following inferential statistics were performed: T-tests,
Spearman’s correlation and regression analysis. To provide the level of significance at which the null hypothesis would be rejected, p-values were calculated. According to Ellis and Steyn (2003) practical significance is measured by effect size which is independent of the size of the sample. A large enough effect size indicates a large enough effect to be important in practice. Effect sizes were calculated to give an indication of the practically significant differences between the student and manager groups.

A literature review was conducted to map graduate attributes of questions in questionnaires to graduate attributes in literature (see Theoretical background above). A pilot study for completing questionnaires was done to ensure the face validity of questionnaires. An exploratory factor analysis was performed to ensure construct validity. Due to all attributes loading to one factor and the Cronbach alpha coefficient (0.84) indicating high internal consistency, the decision to consider all graduate attributes separately and not as one factor score, was made in order to allow more information to be retained.

The software SPSS version 25 was used for analysing data and Statistical Consultation Services of NWU provided assistance.

RESULTS AND DISCUSSION

Table 1 presents the manager participants’ demographic and company characteristics. Of the companies where students worked, 43.2% were small (fewer than 51 employees) with 54.1% being in the IT industry. There were companies where more than one student worked during the same time period.

Table 1: Demographic and company characteristics of managerial participants

<table>
<thead>
<tr>
<th>Factor</th>
<th>Subgroup</th>
<th>Respondents</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Type of Industry</td>
<td>Industrial (e.g. manufacturing; agriculture; forestry and fishing)</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td>Information Technology</td>
<td>99</td>
</tr>
<tr>
<td>Size of company</td>
<td>Small (1-50 employees)</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>Medium (51-200 employees)</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Large (201-10 000 employees)</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Very large (10 000+ employees)</td>
<td>14</td>
</tr>
</tbody>
</table>

Table 2 shows the student participants’ demographic and work placement characteristics. Of the students, 58.4% worked in the IT industry and 39.6% had previous work experience of more than two weeks. Students were mostly male (79.2%), 20 years old (55.2%) and Afrikaans-speaking (89%). Of the students, 70.1% studied IT.
Figure 1 indicates the statistical significant ($p < 0.01$) results of the independent T-test which revealed medium to high effect sizes that varied between 0.48 and 0.68 for managers and students regarding the graduate attributes communication, “initiative or self-motivation”, “planning and organising”, integrity and time management. In practice this indicates that managers assessed these graduate attributes of students better than students themselves.
Table 3: Results of Spearman’s correlation

<table>
<thead>
<tr>
<th></th>
<th>4. Indicate your age</th>
<th>10. How challenging would you rate your work experience gained during the time in practice?</th>
<th>11. In your opinion, does the time period of experience in practice improve your employability?</th>
<th>16. In your opinion, does the time period of experience in practice lead to the possibility of full-time job offers for you?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teamwork</td>
<td></td>
<td>.160**</td>
<td>.182</td>
<td>.184*</td>
</tr>
<tr>
<td>Analysing and Investigating</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initiative or Self-motivation</td>
<td></td>
<td>.181*</td>
<td>.184*</td>
<td></td>
</tr>
<tr>
<td>Self-awareness</td>
<td></td>
<td></td>
<td>.177</td>
<td>.186*</td>
</tr>
<tr>
<td>Integrity</td>
<td>.184*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress tolerance</td>
<td>-.257**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Results of the Spearman’s correlation between students’ opinions regarding graduate attributes, work experience and age are given in Table 3. The degree to which the work was challenging, improvement in employability and the possibility of full-time job offers were indicated according to 4-point Likert-type scales. The question regarding age had response categories 19 or younger, 20, 21 and 21+. The question regarding the degree to which the work was challenging had response categories not at all challenging, slightly challenging, moderate challenging and very challenging. Response categories for the questions regarding improvement in employability and the possibility of full-time job offers ranged from strongly disagree (1) to strongly agree (4).

Stress tolerance and challenging work experience, had a medium negative correlation (-0.257), that was statistically significant. Therefore, students with poorer stress tolerance, experienced the WIL work to be the more challenging.

The graduate attribute “analysing and investigating” and the possibility of full-time job offers had a medium, positive correlation (0.192), which was statistically significant. The better students rated their analysing and investigating skills, the more they agreed that full-time job offers were possible. A medium, positive correlation (0.184), which was statistically significant existed between the graduate attribute “initiative or self-motivation” and the possibility of full-time job offers. The better students rated their own “initiative or self-motivation”, the more they agreed that the possibility of full-time job offers existed. Integrity and the possibility of full-time job offers had a medium, positive correlation (0.186) which was statistically significant. The better students rated their own integrity, the more they agreed that full-time job offers were possible.

A medium, positive correlation (0.181), which was statistically significant existed between the graduate attribute “initiative or self-motivation” and the improvement in employability. The better students rated their own “initiative or self-motivation”, the more they agreed that the WIL activity improved their employability. Self-awareness and the improvement in employability had a medium, positive correlation (0.177), which was statistically significant. The better students rated their own self-awareness, the more they agreed that the WIL activity improved their employability.

A medium, positive correlation (0.160), which was statistically significant existed between teamwork and the degree to which the work experience was challenging. The more challenging the work during WIL was considered, the better students rated their ability to work in a team.

Age and integrity had a medium, positive correlation (0.184), which was statistically significant. The older the students, the better they considered their level of integrity.
Regression analysis revealed time management had a positive, statistically significant contribution to module marks (p=0.001), i.e. the better time management skills were rated, the higher the module marks. The R-square was 0.091, indicating that the regression explained 9.1% of the variance in module marks.

Qualitative results revealed that the most important skills students learned during WIL (Figure 2) were communication, practical skills and teamwork. The most important personal aspects that students needed to improve to promote success in careers (Figure 3) are self-awareness (16%), self-confidence (16%) and patience (11%).

CONCLUSION

In the study on which this paper is based, graduate attributes of IT students participating in a WIL activity were investigated where the perspectives of both students and managers of companies where students worked, were considered. The first research question regarding the difference between management’s and students’ perspectives on graduate attributes was answered. Managers regarded the graduate attributes integrity, communication, “initiative or self-motivation”, “planning and organising” as well as time management of students to be better than what students considered their own attributes. Students and lecturers can therefore be positive that the above soft skills are already being developed whilst studying.
The second research question regarding the relationship between students’ perspectives on graduate attributes and module marks for the Systems Analysis and Design or Business Management modules, revealed time management had a positive contribution towards students’ module marks. The better the time management skills, the higher were the module marks. Lecturers can therefore further give guidance to the students on the topic of time management as it was seen that module marks and this skill had a positive relation. In answer to the third research question regarding the most important skills learnt by students, communication, practical skills and teamwork were considered most important. The most important personal aspects that needed improvement to promote success in careers, were self-awareness, self-confidence and patience. This answered the fourth research question. The significance of the results is that these aspects can be focused upon in self-improvement endeavours when students know their own shortcomings. Other specific aspects to address that came forth from the results were stress tolerance, teamwork capabilities and integrity. The experiences students had during WIL can be used by lecturers in IT courses to change course content, to improve planning for WIL sessions and to empower students to bridge gaps discovered during WIL activities. Results obtained during the study can be used to address shortcomings in graduate attributes during lectures. In order to improve module marks, time management skills need to be taught. Future work to be done includes the extension of the study to determine tendencies on graduate attributes of students over time. A pre-test prior to WIL, followed by a post-test after WIL can be done to analyse the influence of a specific WIL activity on the graduate attributes of students. The questionnaire should be translated into Afrikaans, isiZulu, Sesotho and Setswana to be available in more students’ home languages.

REFERENCES
ABSTRACT
Mathematics education forms an integral part of the first-year student's experience in the Bachelor of Education degree. The study advances diagnostic analytics which explains why something is happening in a particular manner within the Blended Learning course to engage with the challenges of algebra in the mathematics course. The theoretical framework considered in this study is cognitive science using Davis's frame theory. Davis’ theory suggests that student errors in algebra are associated with poorly developed pre-knowledge frames, in particular, arithmetic. The Mathematics Education cohort consisted of 156 students training as pre-service teachers at a University of Technology formed the sample population. A mixed-method research design was applied. All students exam scripts were considered for the quantitative study and a random sample of 26 scripts were considered for the qualitative study. The results from the quantitative study indicated that the students were scoring less than 20% in the algebra section and the qualitative analysis indicated that students were making more structural errors than executive errors. To improve algebra mental frames, a simulation visual-aid such as Mathematica which can be embedded in the learning management system may self-diagnose errors and help improve algebra conceptual cognition.

Keywords: Algebra, Diagnostic Analytics, Blended Learning, Errors and Misconceptions

INTRODUCTION
Reform in education in South Africa has been introduced through initiatives and changes in educational policy, such as the Curriculum and Assessment Policy Statements (CAPS). The new drive is to promote student-centred learning (Department of Basic Education, 2013). A Blended Learning with Diagnostic Analytics course encourages student-centred learning and is necessary to help struggling students to understand basic concepts. Blended learning combines face to face learning with the convenience of online instruction. (Dzuban et al., 2018). A large student population, varying student cognitive capacity and economics, necessitate a Blended Learning approach. Learning analytics (LA) is defined as the analysis of electronic learning data which allows teachers, course designers and administrators of virtual learning environments to search for observed patterns and underlying information in learning processes (Peregrina, Pradas, Gonzalez & Gracia, 2014). Diagnostic analytics indicates why something is happening in a particular manner.

The Blended Learning Model used in the study followed key considerations with regard to assessment. Students had to complete a pre-test based on the concepts being taught in a particular week. An MCQ(multiple choice question) represented a structured activity with restricted outcome. Students were required to submit their written workings and calculations. These would give the tutor and course facilitator an indication of students’ errors and misconceptions. This information would be taken into consideration for lecture design, tutorial support and future assessment. This will be supported by peer assessment on the discussion forum items on the Learning Management System.

The concepts taught in the Blended Learning course is predicated on pre-concepts taught in grade 12. The major misconceptions and errors made by students studying algebra at the Grade 12 level in the RSA National Senior Certificate Examinations (NSC) are well documented in the Diagnostic Reports, Department of Basic Education (2015).

Teaching and assessment in mathematics education must focus on errors (and error analysis) which must explain misconceptions which students experience, and how they can be remedied through appropriate intervention programmes. The pre-service teacher-education units are useful as they provide a training-ground where prospective teacher candidates can learn to equip themselves for these challenges. A possible solution in remedying misconceptions is the use of the discussion forum in the Learning Management System.
System (LMS). Here students can make use of different learning styles. Students can self-diagnose and thus embark on self-directed learning. Students and instructors can use metacognitive processes. In metacognition, students use the LMS discussion forum to engage in internal cognitive processes to communicate. They can communicate, explain and justify the way they think, and can identify with the way others think.

Algebra is challenging to students because they lack the ability to apply basic principles consistently. For instance, when squaring a binomial, they omit the middle term or use the wrong sign between terms. Research by Mulungye, O'Connor and Ndethiu (2016) conducted in Kenya, highlight student misconceptions. Lucariello, Tinec & Ganley (2014) found that these misconceptions impede learning.

The aim of this study is to improve the instructional design material by using diagnostic analytics.

COGNITIVE SCIENCE FRAME THEORY
Observation of students' work gives the facilitator, lecturer or tutor certain insights, ideas and patterns of student thinking. At a University of Technology, the only opportunity is in a small group tutorial setting where student numbers may allow for such interaction. Cognitive science is concerned with student engagement in these activities. perception of information, organisation, storage and retrieval; all of which influence the learning process. Davis (1984) uses cognitive theory as a language to describe mathematical behaviour and adds that knowledge representation structures or “frames” are abstract formal structures stored in memory to encode knowledge where complex frames build on existing ones. According to Minsky (1975), collections of related frames form a frame system. The frame system is made up a network of nodes and relations. The top level of a frame is fixed and represents information that is true of a situation. The lower levels consist of terminals that receive specific instances of data.

Using the definition of a critique as an information processing operator, Davis (1984) outlines possible frame-selecting procedures. Bootstrapping deals with what one sees in the given which leads to associations. Not knowing too much, results from limited knowledge on a topic or concept. Focus on some key cue leads to the retrieval of a specific frame. Context also influences students’ choice. A systematic search occurs when student learning is processed in a systematic way and systematic procedures are used to search the memory. Parameter-adjusting deals with how frames or assimilation patterns have high expectation values.

Algebra consists of a system of frames made up sub-frames that appear as pre-knowledge concepts. When the pre-knowledge frames are adequate, links can be made with new and existing frames.

The error categorisation method (Donaldson, 1963) is used to describe the types of errors. Structural errors are caused by incorrect frame-retrieval and sketchy or incomplete frames, involving deep-level procedures and sub-procedures. An incorrect frame may be retrieved or the frame may not developed adequately. Executive errors occur when there is a failure to carry out manipulations, although the principles may have been understood. The main cause for this type of error is a defect in concentration, attention or immediate memory. A correct frame may be retrieved but a sub-frame responsible for calculations may be underdeveloped. Arbitrary errors are those in which the subject behaves arbitrarily and fails to take into account the constraints laid down in what was given and this is due to mapping incorrect inputs in the retrieved frame.

METHODOLOGY
The overall reading of the student scores in the Algebra component of the final examination paper in Figure 1 is compared with the examination score in Figure 2. The Algebra component of the examination consisted 25 per cent of the examination paper. The Algebra component of the final examination was used to identify errors and misconceptions.
Questions were based on quadratic equations, inequalities, simultaneous equations in two variables, surds, exponents, nature of roots and simplification of logarithms.

The questions in the exams were moderated and therefore the scores were reliable. The quantitative data were valid in that the scores were moderated. Further qualitative data were valid because the scores correlated with the categories of errors.

Students from the School of Education, Natural Science Department were targeted for this study. Permission was sought from the Institution to carry out the study, and all candidates provided written consent to use the data for research purposes. The 156 students were made up of male and female students, aged between 18-33. All students were computer-literate and had access to the open computer laboratories to log into their online classrooms. The majority of the students gained admission to the university with a National Senior Certificate (NSC) with the requirement for mathematics being a minimum of 50 per cent. Mathematics scores and algebra scores for the mathematics education student population were used to determine the success rates.

The sample size was determined by the equation $n = \left(\frac{z \sigma}{d}\right)^2$ where $n$ is the sample size, $z$ is the standard variable, $\alpha$ is the level of significance and $d$ is the error bound. (Bhattacharya, 1977). Selecting a 95% level of significance, $z = 1.96$, $d = 0.85$, $\sigma = 2.2$ (pilot study) and $n = 26$. A random sample of 26 examination scripts was used to source data concerning student errors and misconceptions. Items a-to-k are categorized as follows:

(a) factorisation (standard form);
(b) quadratic inequality;
(c) factorisation (non-standard form);
(d) factorisation (fractions);
(e) simultaneous equations (quadratic form);
(f) surds and exponents;
(g) exponential equations;
(h) nature of roots;
(i) logarithms;
(j) quadratic equations (completing the square); and
(k) quadratic equations (fractions).

This course is offered using the Blended Learning Model. Items from the formal lectures would be supported by posts in the discussion forum in the virtual classroom. Student access was also possible through online applications that were smartphone-friendly. Others could also use tablets and laptops to gain access to online material using the free internet service offered on campus.

Student examinations are conducted at a special examination centre for all students. Student examination scripts were scored according to the official marking memorandum and were thereafter externally moderated.

RESULTS

Quantitative data analysis

The percentage scores for the algebra component was recorded for each student (Figure 1).
Qualitative data analysis

A frequency table for structural errors, executive errors and arbitrary errors was performed.

Table 1: Frequency of Errors

<table>
<thead>
<tr>
<th>Item</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>D</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error Frequency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural</td>
<td>12</td>
<td>0</td>
<td>6</td>
<td>4</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Executive</td>
<td>0</td>
<td>16</td>
<td>2</td>
<td>4</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Arbitrary</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Item</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td>j</td>
<td>k</td>
<td></td>
</tr>
<tr>
<td>Error Frequency</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Structural</td>
<td>15</td>
<td>16</td>
<td>8</td>
<td>6</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Executive</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Arbitrary</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION

The diagnostic report from the NSC examinations also indicated weak frames in Algebra, particularly quadratic equations, exponents and surds were problematic.
Figure 1 indicates that the students were achieving low scores in algebra. The algebra scores ranged between 0 and 20%. The overall mathematics scores clouded the low achieving algebra scores. Scores revealed that students who presented weak pre-conceptual frames in Algebra achieved a poor score in the overall examination. However, the majority of the students were able to pass the mathematics course. The graph showed that 47% of the students passed this section and 53% failed.

Figure 2 depicts the mathematics scores skewed to the left; and this is consistent with the fact that students’ algebra scores indicated that this was the constraining factor. Only 10% of the students scored a mark of 60% or more. Almost 40% of the candidates got an overall score of less than 30%. The graph shows that 42% of the candidates passed and 58% failed the examination.

Table 1 indicates that students were still making structural errors, executive errors and arbitrary errors. In item (a), in spite of the fact that many students were able to score full points, twelve structural errors were recorded. This is possible due to the fact that students were not checking the factors before writing out the roots to the equation.

**CONCLUSION**

Students were passing the mathematics course; however, algebra was an impediment. The results from the final examination Algebra component and the learning management system indicate that students were making more structural errors than executive errors. Davis’ theory (1984,4) suggests that student errors in algebra are associated with poorly developed pre-knowledge frames. More students’ pre-conceptual tasks should be used in the discussion forum of the LMS to engage the community of students collaboratively.

There were two and three groups of students with distinct scoring range. The groups can be connected to structural, executive and arbitrary errors.

The discussion forum in the learning management system provides a direct source for gaining insight into student errors and misconceptions in algebra. Course facilitators can capitalize on student experiences to alert them timeously. Remedial measures must be introduced to support underdeveloped frames.

A Blended Learning environment is ideal for introducing further practice examples to remedy the weaker frames at an appropriate point in the student’s course preparation. This can be used to create strategies to promote access especially for the vulnerable student groups. The role of the facilitator must be that of a support-role to students who have specific barriers that impede their understanding of key concepts.

**REFERENCES**


PHYSICS EDUCATION PAPERS
REFLECTIONS OF PROBLEM SOLVING STRATEGIES AMONGST SENIOR AND JUNIOR PHYSICS STUDENTS
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ABSTRACT – Solving complex problems requires one to have an adequate repertoire of problem solving skills. Teaching such skills is not enough to solve complex problems, because most teachers or lecturers reinforce the idea of finding an appropriate formula for well-constructed problems (Ogilvie, 2009) but the problem solving skill fails for ill-structured problems. In this paper, the students have reflected in their problem solving strategies whilst solving physics problems. A questionnaire with categorized problem solving strategies was administered to junior and senior university students, who are taking physics as part of their core curriculum. This research was towards the end of the semester, with the idea of getting a holistic perspective of their problem solving strategies in physics. The results of this study revealed that the senior students employed more of the “expansive” problem solving strategies, compared to the juniors who had used only a few of the “limiting” and “expansive” strategies. Typically, seniors were in the habit of breaking up a problem into sub-problems, frequently used free-body diagrams and thought about the concepts involved in problem solving. The only “expansive” strategy used by the juniors was the breaking up of a problem into sub-problems.

Keywords: expansive strategies, limiting strategies, physics, and problem-solving skills

INTRODUCTION

Physics by its very nature is a difficult subject as it deals with a large amount of problem solving. For there to be progress in any technological society, there needs to be individuals in the work place empowered with strong problem-solving skills (Ogilvie, 2009). According to Altun (2001), problem solving is “to know what to do when you don’t know what to do” (cited in the reference of Caliskan et al., 2010). In this case, problem solving is a cognitive process that relies on the memory to select appropriate activities, make use of them and work with it systematically to achieve the desired outcome (Caliskan et al., 2010). It is commonly known from literature that many students struggle with open, complex and ill-structured (problems without a clear solution) problems, because the problem solving strategies they learnt from high school is highly formula driven (Ogilvie, 2010). In order to solve ill-structured or complex problems, one needs to make use of higher order metacognitive skills. Students know the laws of physics when applied to a problem of a similar nature done previously but fail when confronted with new problems of different dynamical features (Ince, 2018). It is further reported in literature (Marlina et al., 2014) that students who use metacognitive (higher order thinking skills) skills in problem solving are successful at solving problems (Ince, 2018).

In the research by Reddy and Panacharoensawad (2017), it was reported that students’ poor mathematical understanding has become an obstacle in their problem solving abilities. From a physics point of view, the problem that students face in problem solving is their conceptual knowledge of both mathematics and physics that is a requirement to solve quantitative problems (Ogilvie, 2009). Whenever a student has to solve a problem, an equation is required (or derived), and what unfolds is a manipulation of the equation, and that is where one’s efficacy in mathematics becomes important.

Other researchers have clearly demarcated the behaviours of the problem solving abilities of two types of people; namely, expert and novice problem solvers (Chi et al., 1981). Expert problem solvers have a highly organized conceptual understanding of the field and are quickly able to analyze the essence of the task, while novice problem solvers are known to apply a known set of procedures or algorithms to solve problems (Ogilvie, 2009). In the latter scenario, having a knowledge of these procedures will not be sufficient to solve ill-structured problems in physics. It is a desire of teaching to bridge the gap between novice-type behaviors to expert-type behavior, because the origins of problem solving beliefs may be deeply rooted in classroom instruction (Ogilvie, 2009).

It is the aim of this paper to give a reflection of the students’ problem solving strategies that they have used during their course of their studies while solving a broad range of problems in physics. This is converse to determining students’ problem solving strategies for a specific
problem and for a specific topic in a fixed period. Many studies have focused on specific problem solving strategies but lesser studies is focused on the holistic problem solving strategies in physics. Since the complexity of problem solving in physics increases with each year of study at a university, our study is undertaken include both juniors and seniors with the idea of probing their problem solving strategies.

**RESEARCH QUESTION**

What strategies do senior and junior students display in their problem solving in physics at a university?

**CONCEPTUAL FRAMEWORK**

The framework for this study is based on students’ reflections of the strategies they have used as they worked through a broad range of problems in physics. Such a framework is comprised of two categories; namely, limiting and expansive strategies, which has been taken from the work of Ogilvie (2009). In the problem solving context of Ogilvie (2009), it was used specifically for a problem problem-solving situation. The “limited” strategy is applicable to well-structured end of exercise type of problems but fails for ill-structured or open problems (Ogilvie, 2009). On the other hand, the “expansive” strategy refers to students’ confidence in working through ill-structured and challenging problems. In this sense, such problems solvers are appropriately characterized as expert problem solvers. There are many types of problem-solving strategies, as will be seen in the questionnaire, but each of the strategies can be categorized into one of two broad strategies; namely Expansive and Limiting. Such categories are further tabulated in the table below (Snetinova & Koupilova, 2012).

**Table 1: Categories used to classify student’s reflections**

<table>
<thead>
<tr>
<th>Limiting Strategy</th>
<th>Expansive Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolodex equation matching</td>
<td>Rational thought</td>
</tr>
<tr>
<td>Listing known and unknown quantities</td>
<td>Sub-problems</td>
</tr>
<tr>
<td>Prior examples in text or lecture</td>
<td>Diagrams</td>
</tr>
<tr>
<td>Prior experiments in lecture</td>
<td>Concept first</td>
</tr>
<tr>
<td></td>
<td>Real situation</td>
</tr>
</tbody>
</table>

**METHODOLOGY**

This research instrument was of a modified questionnaire presented in the paper of Snetinova and Koupilova (2012) but developed by Ogilvie (2009). The questionnaire, which is shown in the results section, consists of 9 questions and has options for responses such as often, seldom, rarely and never. This questionnaire has been administered to the first year combined Emergency and Podiatry group (61 students) and the second year Analytical Chemistry group (25 students) at a South African university. Students had to choose from one of the strategies in the questionnaire to reflect their problem solving strategies when they solved physics problems. These strategies are then compared to one of the strategies in Table 1 above for comparisons. Further, the problem solving strategies between the juniors and seniors were then compared to each other. Permission was sought from the students (verbally) before conducting this research. The task took no more than 15 minutes to complete and was done towards the end of the semester.

**RESULTS AND DISCUSSION**

**Differences between the junior and senior students’ problem solving strategies**

Comparison between the juniors and seniors reflective problem solving strategies are shown in Table 2 below (Snetinova & Koupilova, 2012). Results between the junior and senior
students’ reflections are given for the options: Often (O), Seldom (S), Rarely (R) and Never (N). In the table below, the first row represents the number of students while the second row represents the respective percentages.

### Table 2: Questionnaire with problem solving strategies and descriptions of it are shown.

<table>
<thead>
<tr>
<th>No</th>
<th>Strategy</th>
<th>Description</th>
<th>Juniors</th>
<th>Seniors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rolodex equation matching</td>
<td>Selection of an appropriate equation that has the same variables as the list of knowns and unknowns</td>
<td>43</td>
<td>71%</td>
</tr>
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<td></td>
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<td></td>
<td>13</td>
<td>21%</td>
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<td>3</td>
<td>5%</td>
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<td>2</td>
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<td>16</td>
<td>64%</td>
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<td></td>
<td>8</td>
<td>32%</td>
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<td>1</td>
<td>4%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>2</td>
<td>Rational thought</td>
<td>Solving a problem in the mind before</td>
<td>20</td>
<td>33%</td>
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<td></td>
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<td>25</td>
<td>41%</td>
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<td>13</td>
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<td>4</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>Listing of knowns and unknown quantities</td>
<td>After reading the problem, a list of knowns and unknowns are made</td>
<td>37</td>
<td>61%</td>
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<td></td>
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<td></td>
<td>16</td>
<td>26%</td>
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<td>6</td>
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<td>18</td>
<td>24%</td>
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<td>6</td>
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<td></td>
<td>1</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>Use of a prior example from the lecture or textbook</td>
<td>Finding a similar example that was used previously solved in class or textbook</td>
<td>16</td>
<td>26%</td>
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<td></td>
<td></td>
<td>49</td>
<td>80%</td>
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<td>10</td>
<td>16%</td>
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<td>13</td>
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<td>12</td>
<td>48%</td>
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<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>Use of a prior experimental idea</td>
<td>Use is made of some idea from an experiment that is closely related to the example done in class</td>
<td>20</td>
<td>33%</td>
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<td>32</td>
<td>52%</td>
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<td>9</td>
<td>36%</td>
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<td>2</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>8%</td>
</tr>
<tr>
<td>6</td>
<td>Breaking of a problem into sub-problems</td>
<td>Breaking up of a problem into small manageable steps</td>
<td>35</td>
<td>57%</td>
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<td>16</td>
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<td>17</td>
<td>68%</td>
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<td>8</td>
<td>32%</td>
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<td></td>
<td></td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>7</td>
<td>Diagram representations</td>
<td>Use of a free-body diagram or sketches or charts to solve the given problem</td>
<td>14</td>
<td>23%</td>
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<td>24</td>
<td>39%</td>
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<td>1</td>
<td>4%</td>
</tr>
<tr>
<td>8</td>
<td>Conception first</td>
<td>Thinking of the problem in the mind before solving it</td>
<td>16</td>
<td>26%</td>
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<td>20</td>
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<td>60%</td>
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<td>0</td>
<td>0%</td>
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<tr>
<td>9</td>
<td>Real-life situation</td>
<td>Solving the given problem in context of a real-life situation</td>
<td>11</td>
<td>18%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>26</td>
<td>43%</td>
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<td>13</td>
<td>21%</td>
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<td>11</td>
<td>18%</td>
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</table>
be. Students in the research of Snetinova and Koupilova (2012), have achieved the highest for this item in the questionnaire, and further their performance for this item exceeds 80%. Although this was a good result, it was pointed out by them that it was an unsurprising result, because students from primary school were taught a similar type of procedure.

The next item in the hierarchy for which both groups of students have performed well is item 6 (juniors 57% and seniors 80%). This item, which reflects students’ way of breaking down a problem into small manageable steps, is considered an “expansive” strategy in problem solving. In this case, students feel that breaking down a problem into sub-problems may bring about some sense of self-achievement for them and is typically a way that experts would follow in their problem solving. An item for which there is a large discrepancy in the results is item 4. For this item 26% of the juniors have reflected that they have seldomly used an example form their lectures (or textbook) to solve a physics problem, while on the other hand, at least more than 50% of the senior students have used such methods or other resources to solve problems. According to Ogilvie (2009), this “limited” strategy of solving a physics problem may be detrimental to the students since they may struggle to solve more novel problems for which there is no working model to proceed. In the other research of Snetinova and Koupilova (2012), less than 30% of the students have used such strategies in solving physics problems and this research correlates well with that research.

An item for which both cohorts of students have displayed similar trends in reflective behaviors is item 5. For this item, only 33% of the juniors have used some idea from an experiment that was closely related to the problem at hand, while on the other hand, at least 50% of the senior students have tried to solve the physics problem likewise. This strategy, although scientifically sound, is a “limiting” approach to problem solving. A further examination of an expansive strategy that is quite evident amongst the seniors is their conceptual approach. A mere 26% of the juniors have adopted this approach in comparison to 60% of the seniors. Expert problem solvers typically follow a conceptual approach.

Another “expansive” strategy for problem solving is the use of diagrammatic representations. Expert problem solvers extensively use this method. For example, in force diagrams, the use of free body diagrams to represent the various forces acting on a body provides an easier alternative to solving a physics problem. In this scenario, a correct force representation in the free body diagram could lead to the correct use of Newton’s Second Law of Motion. For this item (7) in the questionnaire, 23% of the juniors and surprisingly only 12% of the seniors have used such an approach. On the other hand, it is reflected that 39% of the juniors and 52% of the seniors have seldomly used such an approach in problem solving. Students are unaware of the valuable information that is provided in these quantitative representations (Harper, 2006).

A small percentage of students (seniors 28% and juniors 18%) have tried to imagine the problem at hand to a real-life situation (item 9), whilst a further 43% of the juniors and 52% of the seniors have seldomly approached the problem in this fashion. This strategy, which is an “expansive” one reflects the students’ reluctance to solve it in this fashion, but is typically followed by expert problem solvers.

Finally, a strategy called the use of Rational thought (item 2) in problem solving, which is “expansive” by its very nature, is used very sparingly by students. In this case, students were expected to solve the problem in their minds before attempting to do the arithmetic. Only 48% of the seniors and 33% of the juniors have explored this method.

Comparisons of the students’ problem solving strategies in physics between the junior and senior groups of students

Table 3 provides the students’ reflections that can be compartmentalized into one of two categories of problem solving; namely, “limiting” and “expansive” strategies (Snetinova & Koupilova, 2012). The criteria used in the demarcation of the various strategies in Table 3,
was obtained by taking student’s responses of 50% and above in Table 2 of their reflective strategies.

| Table 3: Comparison of the problem solving strategies used by both junior and senior students |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Juniors          | Seniors         |                                |                  |
| Limiting strategy              | Expansive strategy | Limiting strategy | Expansive strategy |                  |
| Rolodex equation matching      | Breaking up a problem into sub-problems | Rolodex equation matching | Breaking up a problem into sub-problems |                  |
| List of knowns and unknowns    | List of knowns and unknowns | Concept first | Prior examples in lecture |                  |
|                                | Prior experiment in lecture |                  |                  |                  |

It is interesting to see that the senior students use many “limiting” strategies and a few “expansive” strategies in their problem solving. As far as the juniors are concerned, they only use one “expansive” strategy and that is breaking up of a problem into small manageable parts. It might seem that they may be indoctrinated this method way back in their school days. The “limiting” and “expansive” strategies used by the seniors may not be sufficient for them to be called expert problem solvers but a borderline between expert and novice type problem solvers.

CONCLUSION

Students’ reflection of their problem solving strategies between the juniors and seniors is average to weak, and indicative of similar beliefs they hold about problem solving (Ogilvie, 2009). Some “limiting” strategies commonly used by both cohorts of students are the Rolodex equation matching and the other strategy that is closely related to this one is the listing of known and unknown variables. Further, there appears to be only one type of “expansive” strategy that was commonly used by both cohort of students and that was breaking up of a problem into sub-problems. This could be because of the teachers reinforcing this idea during their classroom instruction sessions. Besides the strategy relating to the breaking up of a problem into sub-problems, the only other strategy that separates the juniors from the seniors is thinking about the concepts that are involved in the problem before solving it.

One suggestion of improving the problem solving strategies of students is to allow students with an “expansive” mindset to share their skills with those that have a “limiting” mindset of problem solving or mix students with “limiting” and “expansive” strategies to share common problem solving strategies.

REFERENCES


ABSTRACT – This paper reports the findings of a qualitative analysis on the role of implicit scaffolding in facilitating virtual learning of abstract physical sciences concepts. The participant 3rd year physical sciences education students investigated electromagnetic induction (EMI) and the balancing of chemical equations, using simulations. In assessing the role of implicit scaffolding, participants were tasked to reflect on the different activities and mouse clicks within the learning environment using simulations. Data was collected through reflection diaries, follow-up semi-structured focus group interviews and screen shots of interfaces showing learning transitions. Thematic content analysis was then employed in analysing reflection diaries, transcribed textual data and screen shot records, to generate four main themes on the role of implicit scaffolding. Themes included the promotion of self-directed learning, efficient support of guided inquiry, the reduction of cognitive load and adequate pacing of learning outcomes for students of different abilities. It was concluded based on these findings that implicit scaffolding is an important aspect of designing virtual and e-learning science instruction and should be embedded when developing machine learning activities using simulations and virtual laboratories. The findings also indicated that, embedded implicit scaffolding played a fundamental role in pacing students’ progress to higher cognitive levels in their learning of abstract physical sciences concepts. Some context-specific implications for practice and relevant recommendations for further research are also provided herein.

Keywords: Virtual learning, simulations, implicit scaffolding, self-directed learning, guided inquiry

INTRODUCTION AND BACKGROUND TO THE STUDY

Scaffolding entails the ability to progressively move students from a place of little or no understanding to one of greater understanding and eventually more autonomy in the learning process (Wood, Bruner & Ross, 1976). Just like physical scaffolding, traditional scaffolding in learning describes a teacher’s tendency to provide progressive levels of support on which the student attains higher levels of skills, knowledge and attitudes (Chang & Linn, 2013; Quintana, Reiser, Davis et al., 2004) in a particular subject. Usually, as students make step by step progress the support is gradually removed to enable autonomous learning (Ramnarain & Hobden, 2015). During face to face interactive learning, scaffolding is usually provided in the form of written or verbal instruction, prompts and questions. However, in virtual and e-learning the kind of scaffolding provided is rather embedded in the learning design (Moore, Herzog & Perkins, 2013) of particular simulations or virtual laboratories. In virtual science instruction especially, the scaffold prompts are systematically embedded to navigate students from the least to the most difficult simulations in order to minimize cognitive overload (Chen & Law, 2016). In our quest to examine the learning processes that takes place when students use simulations and virtual laboratories to complement other forms of knowledge acquisition, we realised that there was need for an initial assessment of the role of implicit scaffolding in the virtual learning instruction. We also noted that studies in the South African context focus on reporting the learning outcomes (Penn & Ramnarain, 2018), rather than the learning processes within virtual learning environments. Hence in this study we aimed to examine the role of implicit scaffolding in virtual physical sciences learning using 2-dimensional simulations as reflected on by 3rd year students. To attain the aim of this study the following research questions were posed:

How does implicit scaffolding embedded in virtual simulations facilitate the learning of physical sciences concepts?

How do students benefit from implicit scaffolding embedded in virtual simulations during physical sciences learning?

To answer these research questions the following objectives were outlined;
• Firstly to provide a virtual classroom for learning concepts using PhET simulations.
• Secondly to conduct a qualitative assessment of the role and benefits of embedded instruction as implicit scaffolding post-virtual learning sessions.

THEORETICAL FRAMEWORK

The main theoretical underpinning for this study lies in the emerging theoretical framework for implicit scaffolding (Podolefsky, Moore & Perkins, 2014) which has its foundations in Vygotskian theories. Vygotskian theories portray scaffolding as a supporting tool aimed at transitioning a student through the zone of proximal development (ZPD) from what they cannot learn on their own, to what they can autonomously accomplish in terms of skills, knowledge and attitudes (Chamberlain, Lancaster, Parson, & Perkins, 2014). In science, in particular physics and chemistry, scaffolding is essential in navigating students through abstract scientific concepts which are difficult to visualise and comprehend. Usually the scaffolding will be explicit in that instruction will be verbal through questioning and puzzles or written in the form of a manual of set of instructions to provoke critical thinking, when students engage in scientific inquiry on a given topic. These kinds of explicit scaffolding, even though helpful in achieving learning goals have been criticised by some researchers as being highly teacher-centred, thus decreasing the ability for students to think critically. The nature of implicit scaffolding is crafted in a way that the student is guided without necessarily feeling guided (Bonawitz, Shafto, Gweon, Goodman, Spelke, & Schulz, 2011).

The Nature of Implicit Scaffolding in virtual learning

PhET simulations developed by the University of Colorado Boulder are free virtual learning tools which are implicitly scaffolded such that students can engage in learning science concepts with minimal guidance (Moore et al, 2013; Podolefsky et al, 2014). Implicit scaffolding which is not a form of verbal or written scaffolding is systematically embedded in the design of a virtual laboratory simulation or illustration. This design is meant to facilitate the learning process such that the student moves through the ZPD without much guidance from an instructor or laboratory manual (Bonawitz et al, 2011). It also provides a platform where individualised learning outcomes of students are reached without interfering with different learning paces. The main difference of the implicit from the explicit traditional scaffolding is that when embedded in simulations demonstrations and illustrations, the tools provide the necessary guidance to the student but changes the nature of students’ perceptions and reception of the guidance (Latour, 2005). This implies that the student feels totally in control of their learning and does not really feel instructed as in the case of explicit scaffolding.

Difficulties associated with electromagnetic induction (EMI) and stoichiometry

Based on the results of an online poll conducted with participant students it was indicated that learning Faraday’s law of electromagnetic induction was difficult because, the relationship between electricity and magnetism was more complex than students could visualise. They also noted that it was difficult to comprehend the effects of change in time (dt) through a magnetic field and several challenges associated to the flux rule as alluded by the participants in a similar study by Jelicic, Planinic and Planinsic (2017). Also associated with this topic are misconceptions, for example where some students see flux as the flow of a magnetic field (Zuza, Almudi, Leniz, & Guisasola, 2014). Following these identified difficulties, a learning intervention was then designed to cater for these different aspects of electromagnetic induction using PhET laboratory simulations and the accompanying embedded activities in the simulated learning environment. For the learning interventions, the researchers firstly designed lesson plans to cover specific lesson objectives; secondly constructed activities to assess the specific learning objectives, covering all levels of the revised Bloom's taxonomy; thirdly provided the provided participant with reflection questions and screen capture instructions, then began with the tutorial sessions. Figure 1 below shows two levels of scaffold used to attain the learning outcomes of the first intervention on EMI.
As seen in Figure 1 above, students are able to progressively manipulate the relationship between magnetic flux across the different number of turns of a coil, measuring the electromotive force (emf) generated as they change other variable such as time, direction, number of turns in a coil and magnetic poles. After this point they advanced to different aspects of Faraday's law applications in electrical motors, solenoids and transformers.

With regards to balancing chemical equations, 3rd year students expressed difficulties in the general understandings of stoichiometry. As noted in some studies, the balancing of chemical equations is one of the concepts where the direct inter-relation between Mathematics and chemistry comes into play (Marais & Combrinck, 2009). This usually requires that students understand the relationship between relative quantities of substances in a chemical reactions and compound formation in ratios of whole integers (Marais & Combrinck, 2009). Students found the topic abstract due to the complex relationship in applying mathematical principles while ensuring that chemical phenomena are not compromised (Taskin & Bernholt, 2014). Figure 2 below shows the levels of embedded scaffolding for the tasks which students had to engage in.

As seen in Figure 2 above students were able to first balance the equation for making Ammonia, then proceed to separate water and finally combust methane. When an equation was adequately balanced it would be reflected on the embedded scale balance and a smiley face will be flashed on the screen as a reward. In the case where the student got for instance, the combustion of methane equation wrong, an imbalanced scale would be shown and the screen will remain blue. With this kind of embedded instant feedback system, students are able to self-assess, self-correct and eventually progress into the balancing of more complex chemical equations.

**METHODOLOGY**

The study followed a generic qualitative methodology in which data was collected from 10 groups of 3rd year physical sciences education students (n=50) at a South African tertiary
institution of learning. These participants were purposefully selected because they all took courses in physics and chemistry. It is important to indicate here that the groups were carefully constructed by the tutor (one of the researchers), based on the achievement levels of students such that all levels of ability were duly represented in each group consisting 5 members. After identifying the concepts which they considered abstract, via an online poll, students were exposed to alternative virtual learning simulations during 2 tutorials over two weeks for learning the identified concepts. The tutor did not provide any face to face instructional guidance besides elaborating on the learning outcomes targeted at the end of virtual learning sessions.

DATA COLLECTION AND ANALYSIS

Data was collected from each group’s reflection diaries (with guided reflection prompts) and screen shots of tabs within the simulation interphase at the end of each learning outcome for 2 tutorial sessions. The aim of using reflections and screen shots was to assess the role of the implicit instructions that were embedded in the simulations and to examine the visual representations of the embedded controls seen on the screen with each mouse click. Each group had a single reflection diary in which participants’ collective thoughts were captured and a separate document in which their screen shots were captured and pasted with captions. Ten (10) follow-up focus group interviews were thereafter conducted with all the participants to examine students’ perceptions of this kind of implicit guidance and how they benefited from the embedded implicit instructions. Audio recorded data from interviews were transcribed verbatim and all textual data and screen shots were analysed using thematic content analysis with the aid of a Computer-Assisted Qualitative Data Analysis Software (CAQDAS), Atlas ti version 8. Two coders, coded the data separately and consolidated the codes for an inter-coder reliability of 95% in order to diminish subjectivity of the findings. Table 1 below shows a single response to 1 of the six reflection prompts and how the represented data was analysed to generate the themes that emanated.

Table 1: Sample of data analysis steps

<table>
<thead>
<tr>
<th>Reflection prompt</th>
<th>Group written reflection</th>
<th>Summarised categories</th>
<th>Theme generated</th>
</tr>
</thead>
</table>
| How did you perceive the simulation interface and embedded guidance for balancing chemical equations? Please elaborate on your reflection. | We found that the interphase had embedded guidance in the 3 different tabs as seen on the screen shots we provided. When we made an error with the equations, the scale balanced was uneven and we tried again until the product-reactant balance was attained and we got that smiley face. Overall, it felt great to be in charge of our own learning. | - Different levels of guidance  
- Instant feedback  
- Easy to see errors, correct, then proceed  
- Autonomous learning promoted. | Self-directed and autonomous learning |

RESULTS

Based on the analysis of data from reflection diaries, PrtScr shots and focus-group interviews, students reported on their direct engagement with the virtual learning process using the PhET simulations without tutor guidance. The following themes emerged from the analysis.

(1) Self-directed learning

Of the 10 groups of participants, 9 groups indicated that each simulation had three different interphases that guided them in manipulation each aspect of the concepts they investigated. Groups further mentioned that feedback was instant and real time data could be collected.
when changing variables, especially with the EMI investigations. For the balancing of chemical equations, a balancing scale was embedded within the simulations to guide the way equations where balanced. With all of these built-in scaffolds, students indicated that they found these features quite fascinating and could navigate their way through the simulations to attain the learning outcomes after the first ten minutes of the one hour tutorial slot. In the respective groups participants acknowledged that this embedded guidance empowered them to self-teach and assess without any direct assistance from the tutor or lecturer. It was specifically indicated by all the groups of students that, the simulations on the balancing of chemical equations were quite enjoyable because of the game-embedded features like emoticons.

(2) Guided inquiry

Group members of all the 10 groups indicated they followed the implicit instruction to systematically engage in inquiry-based learning. They noted that they were able to set their own investigation questions and answer them, by following the embedded prompts to eventually manipulate variables and collect data from the simulation laboratories. The main observation here again was that they attained the set learning outcomes without feeling as if they were guided.

(3) Reduction of cognitive overload

In the last reflection prompt which asked the students to state what they perceived to be the ultimate benefit of the simulations, they indicated that simulations were designed such that they did not feel overwhelmed with learning too many concepts at a time, hence adequate cognitive load was maintained, through the use of all virtual learning task. They indicated that as with literal scaffolding, the concepts were systematically built on what they already knew in the form of prior knowledge.

(4) Pacing

All groups also reported that they enjoyed the manner in which learning trajectories could be attained at different times for the different groups such that there was no rush in terms of what could be attained when. In essence, within the virtual learning space the pace was well negotiated based on one’s learning ability so that no one was under any pressure to proceed if they did not understand a particular concept, while those who were fast to grasp, were not held back in waiting.

DISCUSSION OF RESULTS

Findings from this study are closely associated with the findings of studies like Moore et al, (2013) who indicated that the nature of implicit scaffolding which is incorporated in simulations laboratories are able to guide students in attaining their learning outcomes with very minimal explicit instructions. One of the principal findings was that students felt that they could benefit in the pacing of tasks such that in some of the simulation laboratories, they were not able to progress without attaining certain milestones. Those who attained the learning milestones made progress while those who did not attain, had the chance to repeat the simulation over and over. This finding concurs with the findings from other studies (Chamberlain et al, 2014; Chen & Law, 2016) where the researchers found that scaffolded guidance promoted time on task engagement with the phenomena that students were investigating. Students also indicated that, guided inquiry was positively promoted (Quintana & Fishman, 2006) and self-directed learning was enhanced, with immediate feedback on tasks as postulated by Reeves and Reeves (2012). Participants enjoyed the fact that learning trajectories can be individualised when implicit scaffolding is embedded in a virtual learning tool. Contrary to these findings some researchers suggest that cognitive load will always be experienced with all forms of virtual learning whether by 2 or 3-dimensional simulations, based on the strain machine learning poses on human senses (Makransky, Terkildsen, & Mayer 2017). However, these cognitive overloads are better managed when using 2-D simulations as is the case with PhET simulations (Makransky & Petersen, 2019).
The main contribution of this study refers to the need for examining the processes that students engage in when learning in virtual spaces, rather than only the products that emanate from virtual learning interventions as reported in Penn and Ramnarain (2018).

CONCLUSION AND RECOMMENDATIONS

Based on these findings we concluded that it is essential to incorporate implicit scaffolding when designing virtual learning simulations and illustrations. Theoretically this ideology is supported by the assertion that scaffolded instructions will usually move students step-by-step across the zone of proximal development (ZPD), to autonomy in the learning process as they strive to understanding abstract scientific concepts. Implicit scaffolding, also facilitates guided inquiry and autonomous learning of abstract scientific concepts by affording students guidance as they construct essential knowledge to answer scientific questions. Some implications of this kind of scaffolding for science instruction, in the South African context include the fact that though implicitly guided, learning is still very much student-centred rather than teacher-centred. That is, students will still feel very much in control of their own learning as oppose to direct lecturing techniques, which limits peer learning and interactions. Based on these conclusions we suggest that further research be exploited on the different levels of embedded instructions that could assist context-specific learning processes, in virtual-science learning. It is also worth investigating students’ perceptions of implicit scaffolding as a mediation tool in virtual science learning and finally employ quantitative techniques to assess, the relationship between the embedded implicit scaffolding and achievement in content tests.

REFERENCES


ABSTRACT – Many students find the transition from high school to university difficult specifically in engineering. It has been established that there is a gap in mathematics ability between high school and university. Internationally the high school curricula focus on increasing access to tertiary institutions. Many of these curricula teach superficial learning to high school students. At University level deep learning is required. Students who do not meet entry requirements for engineering first year have the option to enter an extended program. This paper explores whether the extended program offered at the University of Johannesburg for mechanical and industrial engineering students is perceived as beneficial. A survey was conducted on first- and second-year students that started their qualification with the extended program. The results were statistically analysed. Information from the Higher Education Management Information System (HEMIS) system was used to compare performance of students who completed the extended program and those in the mainstream. Based on the research it seems that the extended program does benefit students.

Keywords: Academic development, extended program, student perception.

INTRODUCTION

Academic development programs are described in different ways. They are called academic development programs, bridging programs, foundation programs and extended programs. For the purpose of this article it will be referred to as the extended program. Academic development programs have been instituted at major universities across South Africa in response to the need for accommodating students from academically disadvantaged backgrounds, specifically in science and engineering programs. (Boug, 2010). The transition from high school to university it was found to be difficult by many students, especially in engineering. This is specifically true for students from previously disadvantaged backgrounds.

It has been established that there is a gap in mathematics ability between high school and university mathematics in South Africa (Wolmarans, Smit, Collier-Reed, & Leather, 2010). Internationally the high school curricula focus on increasing access to tertiary institutions. The high school curricula teach the pupils superficial learning (Hoyles, Newman, & Noss, 2001) while, at University level deep learning is required. For those who do not meet the entry requirements in first year mainstream engineering program, they have the option to enter an extended program. South African higher education has, for a long time now, adopted bridging programs in line with The National Plan of Education (Ministry of Education, 2001). These programs assist and supports motivated learners to access and achieve in their university programs.

RESEARCH OBJECTIVE

Research shows conflicting results regarding the efficiency of this kind of intervention (Case, Smith, & Van Walbeek, 2014, Dhunpath & Subbaye, 2018). It can be inferred that further research is required. The aim of this article is to investigate whether the extended program offered by the Academic Development Centre (ADC) at the University of Johannesburg, for mechanical and industrial, engineering students, adequately prepares students for their entry into mainstream. The following questions need to be addressed:

- Have students improved their knowledge and skills in mathematics, English and computer literacy?
- Have students made the transition from superficial learning to deep learning during the extended program?
How do students’ experience the extended program and what is their perception of the support and efficiency of the communication received in the program?

THEORETICAL BACKGROUND

Superficial learning and deep learning

Often, at high school, students are taught superficially (Hoyles, Newman, & Noss, 2001). At University level deep learning is required (Ro, Lattuca, & Alcott, 2017). The aim of extended programs have been to ensure that students are equipped with certain skills to bridge the gap between high school and university specifically for academically disadvantaged students. One of these skills is to enable students to move from superficial learning to in-depth learning (Kloot, Case & Marshall, 2008). Deep learning or higher order thinking has been found to be a critical predictor of success (Lee & Choi, 2017). Deep learning is the ability to understand and apply knowledge in various environments (Case & Marshall, 2004). Deep learning is associated with understanding, using analytical skills, paying attention to the underlying meaning, cross-referencing and independent thinking. Deep learning tends to be internally motivated by desire to understand and not simply to pass (Warburton, 2003). Students need to become engaged with the study material and this normally follows from developing a strong personal interest in the field.

Controversy regarding the efficiency of extended programs

Conflicting results have been reported regarding the benefits of extended programs. An interesting finding is that students who do well in foundation programs perform better in later degree studies than students admitted directly into mainstream programs (Wood & Lithauer, 2005). However, in other studies it was found that the success rate was lower for students from extended programs than for mainstream students (Mathews, 2012). It was also found through statistical analysis that students from academic development programs did not significantly improve the throughput rates (Case et al., 2014).

Davidowitz and Schreiber (2008) investigated how effective factors correlates with adjustment and academic functioning and ultimately reflects on performance. This study conducted on students in an extended program revealed that “This programme seems to have enhanced the students’ experience and adjustment to University of Cape Town (UCT) and by extension possibly enhanced their academic functioning and performance.”

One of the factors that was found during interviews with students who dropped out from South African universities, was that many of the interviewed students were unable to integrate academically, and that there was no proper academic support to address the needs of students (Moodley & Singh, 2015).

A study was conducted on the foundation program of Natural and Agricultural Sciences at the University of Pretoria. The program had an 18 month long preparatory phase after which the students joined the mainstream program. Their approach was to consider three performance bands, namely good, moderate and poor and report the experience through the lens of each performance band. The study concluded that the poor performance band students voiced their inability to cope with academic demands of programs. These students should be better prepared with regard to academic demands and life skills. This foundation programs will assist them to adapt to the challenges of a university and help them to find assistance if required (Potgieter, Somo, Harding, Engelbrecht, & Kritzinger, 2015).

Success rates of students enrolled in foundation preparatory programs have been steadily increasing over time according to Dhunpath & Subbaye (2018) thus, justifying the substantial increase in funding from the state budget for such interventions. They indicate that, despite the different risk profile of students admitted in extended programs, their success rate is comparable with the mainstream student body and their performance is on the same level as their better prepared peers.

A similar opinion was expressed by Ssempebwa, Eduan, & Mulumba (2012) who analysed the performance of students taking the conventional route versus those taking a bridging
program route. They found that the difference in performance was in favour of the bridging-route category and that may be due to early exposure to the general learning environment. This would reduce, the stressors at the start of the mainstream degree program.

Although the efficiency of extended programs has been scrutinized in various ways, with the use of one criteria or another, the reality as presented by the Department of Higher Education is that almost half the students entering undergraduate degrees, never graduate (DHET, 2017). The students’ under-preparedness may be addressed by this type of intervention however, due to their limited enrolment number in these programs, their success rate contributes very little to the mainstream throughput statistics. Jacobs et al. (2014) concluded that “Institutions should seriously consider placing more students in these programmes to ensure throughput and ultimate graduation.” It is pointed out that, regardless of the financial support from the government towards foundation programs, they do not represent a quick-fix solution to the challenges faced by higher education in South Africa with regard to improved numbers of graduates (Kloot et al., 2008).

In general, the academic research is advocating the usefulness of the extended programs but there are few who argue their effectiveness (Case et al., 2014). Considering that foundation programs initiatives have been around for a long time, there has been ample time to assess and consider improvements. Implementation of these programs should benefit the students not only in knowledge gained but in better integration into the university system. Also these programs should aid with increased throughput rates.

Extended program
What initially started as bridging programs with the intention of filling the gap between inadequate schooling and demands of academia, have been re-framed in 2005 into foundation programmes. Soon thereafter these became extended curricula in engineering. These programs are now funded by the Government (Case & Heydenrych, 2015). The extended curricula has become a formal degree. The qualification is extended by 12 to 18 months, depending on the Higher Education Institution.

At the University of Johannesburg (UJ), the extended program for engineering students is offering introductory courses in key subjects and aims at developing student’s academic literacy and learning skills. It is designed to prepare a more diverse student body by improving the graduation rates of previously disadvantaged students.

The Bachelor in Engineering Technology (BET) is a three-year program, whereas the BET extended program is a four-year program. The BET extended offers the same modules for both mechanical and industrial students in their first year. The students in the extended program will have to successfully complete all eight of first year academic development modules offered by Academic Development Center (ADC) in order to join the mainstream program. If students fail any one of their academic development modules they will be academically excluded. Their first year experience is different from a mainstream student’s first year experience as this extra year will reinforce knowledge, and allow time for better academic integration. The modules offered by ADC extended program are shown in Table 1. Characteristic features of this additional year are:

- The syllabus of one semester is extended over the entire academic year so that there is enough time for profundity and deep learning;
- There are components of Life skills (i.e. Workplace preparation) where issues like goal setting, time management, study skills, exam stress and integration to university environment are addressed;
- The foundation mathematics and physics are reinforcing the high school knowledge. New topics are covered in depth in order to better prepare for the demands of the qualification;
- The program provides basics computer skills and facilitates revision of high school English language.
Table 1. First year modules in the extended program in mechanical and industrial engineering

<table>
<thead>
<tr>
<th>Code</th>
<th>Module Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPSED01</td>
<td>Computer Skills (Year Module)</td>
</tr>
<tr>
<td>FOMED01</td>
<td>Foundation Mathematics (Year Module)</td>
</tr>
<tr>
<td>FPYED01</td>
<td>Foundation Physics (Year Module)</td>
</tr>
<tr>
<td>FRRED01</td>
<td>Fundamental Research Practice (Year Module)</td>
</tr>
<tr>
<td>MDRED01</td>
<td>Mechanical Engineering Drawing (Year Module)</td>
</tr>
<tr>
<td>PMEDP01</td>
<td>Physics (Mechanics) Practical (Year Module)</td>
</tr>
<tr>
<td>PMEDT01</td>
<td>Physics (Mechanics) Theory (Year Module)</td>
</tr>
<tr>
<td>WPPED01</td>
<td>Workplace Preparation (Year Module)</td>
</tr>
</tbody>
</table>

**METHODOLOGY**

To determine whether the extended program prepares students adequately for their engineering studies a questionnaire was developed for surveying these students. This study was a quantitative research study. There were 29 questions in four sections. The sections were:

A. demographics,
B. questions about the specific subjects,
C. progress and communication during the extended program and
D. experience gained and lessons learned during the extended program.

Likert scale was used as well as polar questions for the closed ended questions and there were 4 open ended questions.

Questions were developed based on informal interviews with students about their experiences in the extended program. Personal experience as lecturers in mechanical and industrial engineering have revealed general concerns regarding language, mathematical proficiency and communication abilities. These were explored further in the questionnaire. Literature also guided some of the questions asked about in depth learning (Kloot et al., 2008) and about adjusting to the university environment (Davidowitz & Schreiber, 2008).

The questionnaire was given to first and second year mechanical and industrial engineering students studying Extended Bachelor in Engineering Technology in the Mechanical and Industrial Engineering Technology Department (MIET) at UJ. A total of 122 students completed the questionnaires out of a total of approximately 170 students that started in the extended program. Mechanical and Industrial engineering students at UJ come from various cultures, socio-economic backgrounds and home languages. All teaching and learning at UJ is in English so all students should have a basic proficiency in the English language.

First year students were asked to complete the questionnaire as they were still at the beginning of their engineering studies and their experience in extended program was recent. The second year students that have already finished their first year, would have better insight as to the benefits of the extended program to their engineering studies. Of the responses 54% were from first year students and 46% were from second year students.

We obtained ethical clearance from the University Ethical Committee for this research. Students were approached in one of their class periods. Participation was voluntary and anonymous.

The questionnaire contained both open and closed ended questions. Data was captured and analysed using IBM SPSS Statistics.

The Higher Education Information Management System (HEMIS) data was interrogated to compare, the percentage achieved in mathematics and science of the students who started in the extended program with the students in the mainstream.
Reliability was achieved by using Cronbach alpha testing. This is a measure of internal consistency.

RESULTS AND DISCUSSION

The statistics showed that a larger number (54%) of the students surveyed were first year students. The reason was some students drop out at the end of their first year and therefore there is a smaller second year class. There were more industrial engineering students than mechanical engineering students as annually the university accepts approximately 60 students into the extended program for industrial engineering technology and only 40 for mechanical engineering technology. The university accepts approximately 45 students into mainstream for industrial engineering technology and 80 for mechanical engineering technology. Of the 122 questionnaires completed 62% were completed by industrial engineering technology students.

English proficiency

The survey showed that only 13% of the students spoke English as their home language yet 90% of the students were taught mainly in English. This is not surprising as most schools in South Africa offer tuition in native languages until grade three and thereafter students are taught in English. Students reported that they did not experience difficulty with understanding mathematical terms in English, only 8% of students indicated that they experienced some difficulty at the beginning of the course. After the extended program was completed only 2.5% reported that they still experienced some problems with mathematical terms in English. The proficiency in the English language was reported by 84% of students between intermediate and expert. However the authors of this study and their colleagues in the MIET department, regularly experienced that students did not understand the questions in test and exams. It was apparent from reports written by students that the grammar and spelling of English were lacking and sometimes it was difficult to understand what students were trying to say. Language is therefore still considered a problem even though students are taught mainly in English and they report proficiency in the language.

Enjoyment and difficulty of subjects

In the section on specific subjects, students reported that they enjoyed the subjects in the extended program as indicated in Table 2. However, 54% of student reported that they found engineering drawing difficult. The reason given was that they did not have the subject in high school and it was new to them. Physics (Mechanics) Theory was also identified by 52% of students as a subject they experienced difficulty with, see Table 2. Students reported this subject as complex.

<table>
<thead>
<tr>
<th>Enjoyed subjects</th>
<th>Difficult subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foundation Mathematics</td>
<td>5.80% 94.20% 89.10% 10.90%</td>
</tr>
<tr>
<td>Engineering drawing</td>
<td>33.10% 66.90% 46.60% 53.40%</td>
</tr>
<tr>
<td>Foundation Physics</td>
<td>17.40% 82.60% 84.80% 15.20%</td>
</tr>
<tr>
<td>Fundamental Research Practice</td>
<td>38.80% 61.20% 79.50% 20.50%</td>
</tr>
<tr>
<td>Computer skills</td>
<td>14.90% 85.10% 84.00% 16.00%</td>
</tr>
<tr>
<td>Physics (Mechanics) Theory</td>
<td>21.50% 78.50% 47.90% 52.10%</td>
</tr>
</tbody>
</table>

The extended program assisted students to become familiar with the administration processes at the university. Over 90% of students reported that they became familiar with the universities exam and test regulations and over 80 % reported that they became acquainted with the university rules and regulations. During the extended program it was easy to adapt to the university environment according to 72% of students.
Transition to deep learning
The responses of 87.7% of students agreed and strongly agreed that they were now aware of the need to understand the work rather than memorising it. When asked whether they were able to apply knowledge in different environments, 91% agreed and strongly agreed. The majority (92.6%) agreed and strongly agreed that they were responsible for their studies. It appears that the extended program does assist in helping students to progress from surface learning towards deep learning as can be seen in Figure 1. To truly establish whether deep learning is taking place further investigation is required regarding their ability to apply knowledge.

![Image](image.png)

Figure 1: Results from questions regarding deep learning

Communication and support services
Students agreed and strongly agreed (86.1%) that the subject promotion requirements were clearly communicated by lecturers. The majority (81.4%) indicated that they were now moderately familiar and extremely familiar with various support services at the university.

Future plans
Of the students who completed the questionnaire, 79% of students agreed or strongly agreed that the extended program positively contributed to their aspirations to become engineers. Future plans in terms of dropout can be seen in Fig. 2. In the survey 5% of students indicated that they were planning to leave or seriously considering to leave the engineering program after the extended program and 11% were neutral about leaving. When the number of students who drop out are taken into consideration, 5% of students considering or planning to leave is low. It might be that these are a portion of the students who might voluntarily drop out and not drop out because of other factors such as finance or poor academic performance.
Benefits of the program
Students were asked in an open-ended question how the extended program benefitted them the most. Some of the responses were:

“Adapt to university easy and be familiar. It gives me aspirations to become an engineer.”

“Allowed me to enrol in this Degree (through extended). Not too sure if I would be accepted into regular course.”

“Helped me adapt to the university life and helped me have a better handle on my future and academic development.”

“It has increased my language a lot. It also taught me how to be independent in terms of academic life. It even helped me to be familiar with the university environment.”

“It helped me cope with pressure and be able to depend on myself and team to get things done.”

“It helped me most on mathematics and some modules whereby I can easily determine which best way to study or achieve pass for my test and exams (sic).”

“The extended programme gave me the fundamentals necessary for pioneering my career as an engineer. It gave me basic math and physics principles”

Three students reported that it had been a wasted year and that the work was too easy. It seems that many of the students benefitted from the extended program because it assisted them with the realisation that they needed to work hard and take responsibility for their work. Language skills and fundamental knowledge in mathematics and physics were also improved. The extended program appears to have eased the transition to university environment.

Comparison of academic results
From the HEMIS data the performance of the mainstream students were compared with the performance of the students from the extended program. These students were together in the same class, with the same lecturers. The pass rate of students in the course at the end of the semester, were higher for students from the extended program as indicated in Figure 3. There was a more pronounced difference in traditionally difficult subjects, such as electronics, technology and mathematics, where the failure rates are high. It is still too early to compare graduation rates as this qualification is new, and 2016 was the first year for enrolment into this course. A longitudinal study will be done to track the differences between these groups.

Suggestions for improvement
When students were asked in an open ended question to give suggestions to improve the extended program some of the responses were:
“I think they should put breaks in some classes and student shouldn’t be expected to attend from 8 - 5 every day it is too exhausting (sic).”

![Figure 3: Percentage of students passed per subject](image)

“Add more breaks between classes as it is hard to focus on every class”
“Add more breaks between classes as it is hard to focus on every class”
“Time table is too full.”
“Time table is too full.”
“To communicate well with the student.”
“To communicate well with the student.”
“I think learners need to be more informed of the benefits in the extended program and they should be advised about it and they should be told not to take an extended program lightly”
The students specifically had no lunch break.

CONCLUSIONS

This study showed that students in the extended program seemed to be better prepared in terms of foundation knowledge for mainstream studies. Student experienced a more gradual transition into the university environment. Students were generally positive about their experience in the extended program and perceived many benefits from it. A few students were frustrated by the level of the work, finding it too easy. It may be that the students who were frustrated did not come from academically disadvantaged backgrounds. This could be explored further.

Students from the extended program seemed to perform better than students directly from high school into the mainstream, when their performance is compared per subject. This is especially so for the more difficult subjects. Therefore, the study may indicate that the extended program bridges the gap between high school and university. Further research will be required to confirm.

From the survey results it appears that students from the extended program have made the transition to take responsibility, make the effort and ensure that they understand the work rather than just rote learning. These students also report to adapting to university with ease.

RECOMMENDATIONS

Further research is required to establish whether deep earning is truly taking place. A Longitudinal study is also recommended to track the performance of students who started in the extended program compared to those who started in mainstream. This will provide confirmation that the extended program bridges the gap to university and is to the benefit of the students.

Based on the study it is clear that the timetable should be adjusted to provide a lunch break for students.

REFERENCES


USE OF TARGETED WEB-BASED INSTRUCTION TO ENHANCE LEARNERS’ UNDERSTANDING OF ASTRONOMY CONCEPTS

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ABSTRACT – Primary school learners often use naïve ideas rather than normative notions to understand Astronomy concepts, because they rely on inadequate mental models to decipher the concepts. This paper reports on findings from the use of Targeted Web-Based Instruction (TWBI) to enhance Grade 4 learners’ understanding of Astronomy concepts. Targeted instruction involves the identification of learners’ different levels of understanding in order to provide them with information that is within their level or zone of proximal development. The TWBI involved the use of web-simulations, applications, search engines, and web links to multimedia to study Astronomy concepts that learners perceived as difficult. An online achievement pre- and post-test was used to collect quantitative data from 27 Grade 4 learners from a primary school in Johannesburg. In addition, a Web-Attitude Scale (WAS) and individual semi-structured interviews were used to collect qualitative data. The findings revealed a statistically significant improvement (p<0.001) in learners’ post-test scores and in their attitude towards the study of Astronomy. We argue that the use of TWBI could enhance learners’ understanding of Astronomy concepts.

Keywords: Web-based, Instruction, Astronomy, Targeted.

INTRODUCTION

In South Africa, Natural Science is a compulsory subject offered in the Intermediate Phase (Grades 4 to 6) curriculum (Department of Basic Education [DoBE], 2011), and it includes a learning unit titled Earth and Beyond (DoBE, 2011). In Grade 4, the Earth and Beyond unit focuses on the study of planet earth, the earth and the sun, and the moon (DoBE, 2011, p. 27-30). The existence of celestial bodies beyond the skies fascinates young people. Kallery (2000) asserted that this fascination with astronomical phenomena evokes numerous enquiries and perplexities. When young learners are fascinated by seeing the sun ‘set’ or ‘rise’, and the moon appearing at night, they develop ontological ‘big ideas’ that guide their conceptions of these celestial bodies. Young learners tend to understand these phenomena by developing intuitive ideas based on naïve and causal theories that inform their interpretations (Kallery, 2000). Vosniadou and Brewer (1994) and Agan (2004) have established that learners often use inadequate mental models when learning Astronomy, mostly because they rely on naïve and causal ideas to construct their understanding of the relationship between the earth, moon, sun and the solar system in general. In this regard, Nthimbane, Ramsaroop and Naude (2017) suggested that ‘like scientific theories, intuitive ideas are composed of a combination of causal laws and ontology that determine how various concepts interrelate’ (p. 305). Although these are not scientifically proven notions, a young learner holds them to be true until a new theory that provides more conclusive evidence is taught or learned (Gopnik & Wellman, 2012).

In the South African context, the problems facing young learners beginning to learn Astronomy concepts is compounded by the fact that they are simultaneously transitioning from being taught in their native languages to being taught in English in Grade 4 (Pretorius, 2014; DoBE, 2011). Learners therefore face the dual challenge of learning complex Astronomy concepts in an unfamiliar language – English, which is a second or even third language to most South African learners (Snow, 2010).

Another challenge facing young Astronomy learners is that South African teachers predominantly use traditional methods to teach the topic, where teachers are seen as the main source of information, with limited use of technology. They also rarely emphasize the development of learners’ prior knowledge. In this regard, Mnyamane and Naude (2016) have argued that ‘teachers at the primary school level pay limited attention to their learners’ prior-knowledge and to naïve theories about the natural world, when introducing scientific concepts’ (p. 507). These authors further inferred that primary school teachers in South
Africa ‘do not establish pedagogies that address these attributes in the instruction process’ (Mnyamane & Naude, 2016, p. 507).

Given these challenges, an instructional approach, which explicitly demonstrates the Astronomy concepts perceived as difficult by learners, could enhance their transition from naïve to normative understanding of the concepts. In South Africa, there is a dearth of literature on instructional methods for enhancing Grade 4 learners’ understanding of the Astronomy. It therefore became necessary to develop an instructional intervention that attempted to assist learners in the process of theory formation, refutation and change. The questions addressed in the study were:

1. How does TWBI affect learner achievement in an assessment on Astronomy concepts?
2. What are Grade 4 learners’ perceptions regarding the use of web-based instruction to learn about Astronomy concepts?

THEORETICAL BACKGROUND

The concept of constructivism was used to guide this study. According to Vygotsky (1934), cited in Liu, and Matthews (2005), ‘Learners are believed to be enculturated into their learning community and appropriate knowledge, based on their existent understanding, through their interaction with the immediate learning environment’. Based on the thinking of Vygotsky, it was assumed that learners could construct their understanding of abstract Astronomy concepts. Two features of constructivism are prominent, namely cognitive constructivism and social constructivism. This study was premised on the empirical work of cognitive constructivists such as McInerney and McInerney (2002), and Liu and Mathews (2005), who argued that knowledge is individually constructed through learner-centred and discovery-oriented learning processes. In line with cognitive constructivism, Grade 4 learners were provided with instruction that targeted the unique misconceptions or incorrect responses they produced in the pre-test. The learners were also individually engaged in mini research projects and virtual experiments to enhance their understanding of selected Astronomy concepts. The social context provided by peers functioned as motivation for individual cognitive development.

METHODOLOGY

Research design and sample

The study employed a sequential mixed methods research approach, involving a single group pre- and post-test experiment. Participants were selected using purposive sampling, because they were expected to study Grade 4 Astronomy topics stipulated in the CAPS document. The participants comprised 27 Grade 4 learners from an intact class in a school in Soweto, Johannesburg, enrolled for the 2018 school year. The class contained 16 male and 11 female learners, aged between 9 and 11 years.

Development of TWBI materials for intervention

In order to develop the TWBI materials, Astronomy concepts were identified based on learners not showing competence in them in a pre-test. These were then categorized into themes that included movements of the earth and the moon, features of the earth, moon and the sun, phases of the moon, the relationship between the earth, moon and sun, as well as the planets in our solar system. Concepts from these themes were incorporated into the TWBI materials used for the intervention. An experienced Grade 4 teacher and two primary school science education specialists reviewed and approved the TWBI materials.

Instrumentation

The instruments used to collect data were an Astronomy achievement test, a Web-based Attitude Scale (WAS), and a structured interview schedule. The researcher developed the achievement test instrument and a structured interview schedule in collaboration with an experienced Grade 4 science teacher and two specialists in the field of primary school
science education and assessment. The WAS instrument was developed by Loyd & Gressard (1985), revised by Nash & Moroz (1997), and adapted for the South African context by the researcher. This adaptation by the researcher was done with the objective assistance of the experts who were involved in developing the test and interview schedule.

The involvement of primary school science education experts in the development of data collection instruments was meant to enhance their validity. These specialists were required to develop and review the instrument items to ensure that they were:

- related to the Astronomy topics under investigation
- in line with the South African Natural Science CAPS document
- clear, suitable and comprehensible to Grade 4 learners
- grammatically correct

All the instruments were also validated in a pilot study, using five Grade 4 learners who did not participate in the main study. After the pilot study, items in all instruments were revised, and those that did not meet the stated criteria were either discarded or modified.

The achievement test assessed learners’ competence in Grade 4 Astronomy topics, while the WAS and the interview schedule were used to determine (i) learners’ interest, access and attitudes towards the use of computers and the internet for teaching and learning purposes, and (ii) learners’ knowledge of Grade 4 Astronomy concepts. The latter was done in order to triangulate the quantitative findings.

Research process

The achievement test, which consisted of 26 items, was administered to learners as a pre-test for two reasons. The first was to determine learners’ baseline knowledge of stipulated Grade 4 Astronomy concepts. Secondly, it was used to identify Grade 4 Astronomy concepts that learners found difficult to understand. These, in turn, were used to guide the development of TWBI materials for the intervention. In addition, The WAS questionnaire was also administered prior to the intervention.

After the pre-test, learners were exposed to TWBI materials for seven 30-minute lessons, which took place over a period of three weeks. The intervention, which occurred during school time at the schools’ computer centre, was meant to enhance participants’ understanding of the identified difficult Astronomy concepts. Learners used web-simulations, applications, search engines and web links to multimedia, such as videos, animations, games and age-appropriate websites to learn about the earth, moon, sun, and the solar system. Learners were provided with research problems and web links, the latter of which were generic for all the lessons. However, unbeknownst to the learners, they received different solar system research problems to investigate, based on their performance in the pre-test.

Subsequently, the same achievement test and WAS survey were again given to the participants as a post-test. The purpose of this post-test was to determine the effect of the intervention on learner achievement and on their views about the use of computers and the internet for learning purposes. Out of the 27 learners who received the WAS questionnaire, only 21 learners completed it. The performance of learners in the pre-test and post-test, as well as in the WAS survey, was subsequently compared. Furthermore, five of the participants, comprising learners from the top 10% and bottom 10% of the post-test scores, were interviewed after the intervention.

Data analysis

Quantitative data from pre-test and post-test scores were compared using a histogram and paired sample t-test. These comparisons aimed to determine the effect of the intervention on the learners’ achievement in Astronomy topics related to the learning unit Earth and Beyond.
For the t-test, a level of significance equal to or less than 5% (p ≤ 0.05) was considered a statistically significant difference.

Seidel’s (1998) model of qualitative data analysis (QDA), was used to analyse the data from the WAS survey and interviews. Seidel (1998) postulated that the process of analysing qualitative data involves three parts, namely noticing, collecting and thinking. In accordance with the model, the researcher identified (noticed) and coded responses from the WAS questionnaire and interviews that were relevant to the study. The coded statements were then organised (collected) into themes. These themes were examined to make sense of the data, both within each theme and from the general collection of themes (thinking). The codes used to analyse the data consisted of four elements. For instance, the code “ivM3b” expresses the second statement (b) given by the third male learner (M3), under the fourth theme (iv).

**Ethics considerations**

Permission to involve learners in the study was sought from their parents, the principal, school governing body and the Department of Basic Education. Learners provided assent to participate in the study, after the purpose, nature, benefits and potential risks of the study were explained to them. The researcher informed learners of their right to refuse to participate or to withdraw from the study without repercussions. Learners were further informed that their performance in the assessments and their interview responses would be kept confidential, and that their right to privacy and anonymity were guaranteed. Finally, the research report was made available to the participants, their parents and their teacher, during a debriefing/closure session.

**RESULTS**

The study results are presented in two sections. The first section displays quantitative data from pre- and post-tests, comprising a histogram and inferential statistics. The second section presents qualitative data obtained from WAS survey and interviews.

**Quantitative data**

The displayed quantitative data pertains to the research question: ‘How does TWBI affect learner achievement in an assessment on Astronomy concepts?’ Pre- and post-test scores were initially compared using a histogram, and the results are shown in Figure 1.

![Histogram comparing pre- and post-test scores](image)

**Figure 1: A histogram comparing learners’ pre- and post-test scores.**

Figure 1 shows that most learners (25 out of 27) scored in the ranges of 21 to 40 and 41 to 60 in the pre-test. The mean score in the pre-test was 35.6%. After the TWBI, the majority of the learners (24 of 27) scored in the range of 41% to 100%, with a mean score of 60.7%, which is an improvement of 25.1% from pre-test mean score. The significance of the difference in learners’ pre- and post-tests mean scores was determined using a paired sample t-test, and the result of the comparison is displayed in Table 1.
Table 1: Paired sample t-test comparison of the performance of learners in the pre- and post-tests

<table>
<thead>
<tr>
<th>Assessment</th>
<th>N</th>
<th>Mean score (%)</th>
<th>SD</th>
<th>Mean score difference (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-test</td>
<td>27</td>
<td>35.6</td>
<td>11.06</td>
<td>25.1</td>
<td>0.001**</td>
</tr>
<tr>
<td>Post-test</td>
<td>27</td>
<td>60.7</td>
<td>17.98</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**p<0.05 (critical value)**

The p-value of 0.001 in Table 1 reveals a statistically significant difference between the pre- and post-test mean scores. This quantitative result suggests that learners’ performance in an Astronomy achievement test improved significantly after the TWBI intervention.

**Qualitative data**

The second research question was ‘What are Grade 4 learners’ perceptions regarding the use of web-based instruction to learn about Astronomy concepts?’ In order to answer this question, two themes were considered. The first theme involved determination of learners’ attitudes toward the use of the computers and the internet for learning, and the second was an interrogation of learners’ knowledge of Astronomy. The WAS survey and semi-structure interviews yielded the following results.

**Theme 1: Learners’ interest and attitudes towards the use of computers and the internet for teaching and learning purposes**

Items from the WAS survey sought to determine, before and after the intervention, whether learners felt confident to use computers and the internet. The survey also aimed to determine whether the use of the internet makes learning easier, and whether the internet could enhance academic performance. The findings showed that learners were hardly exposed to computers and the internet during science lessons prior to the intervention. In addition, four of the five learners who participated in the interviews said they had not used the computer centre or the internet for teaching and learning purposes, prior to the intervention, in that academic year. Despite this deprivation, findings from the survey revealed that 57% of the learners felt confident to use computers and the internet.

After the intervention, 42.9% of the learners who participated in the survey indicated that the internet was relevant for teaching and learning purposes, and 48% felt that the use of the internet could enhance their academic performance. These sentiments were reiterated during the interviews, where all interviewed learners indicated that they enjoyed using computers and the internet to learn about the solar system. When asked what they found most interesting about learning in the computer centre, learners’ responses included the following:

vF1a&b. ‘When we played the games, making our solar system’.
vM1a&b ‘It helps you to know the solar system and how the internet works’.

Additionally, all participants responded in the affirmative when asked if they think learning in the computer centre is useful in improving their academic achievement. Based on learners’ responses to questions regarding the intervention, it is clear that they had a positive attitude towards the use of computers and the internet as learning devices and that they felt that these resources enhanced their knowledge of Astronomy concepts.

**Theme 2: Learners’ knowledge of Astronomy concepts**

This theme was aimed at establishing learners’ knowledge of Astronomy concepts, including the earth, moon and sun, after the intervention. Learners’ responses suggest that they acquired basic knowledge of these celestial bodies. These assertions are evident in the following quotations; iF1a&b, ‘What I have learned about the earth is that the earth has its own axis….’; iM2a, ‘I’ve also learned that the features of the earth are water, land and air’; iiM1a, ‘I learned that the moon has rocks and it has, the holes are called craters’. In addition, some learners thought that learning about these concepts had significance to future learning,
as indicated in this quotation; iiiM2b, ‘Yes, b—Because in other grades we need to make a book about the sun and it is important to remember the information’.

From learners’ responses, it appears that the majority of them held a normative understanding of the features of the sun, earth and the moon, and the movements of the latter two bodies, after the intervention. This finding corroborates the improvements observed in the quantitative data. However, despite these improvements, some learners did not seem to know the difference between certain Astronomy terms, such as rotation and revolution, as indicated in these statements; iF1a&b ‘What I have learned about the earth is that the earth has its own axis and that the earth rotates around the sun’. iiF2b ‘We learned that the moon is it rocky and it is a sphere and it rotates around the earth’. Learners’ limited capacity to express themselves in English could account for this limitation.

DISCUSSION OF RESULTS

The quantitative results revealed that the use of TWBI to teach Grade 4 Astronomy concepts significantly enhanced learners’ achievement in the topic, despite the fact that they had had limited exposure to tools (computers and the internet) used for the intervention. This improvement is not surprising as the TWBI used provided learners with control over the content taught, which could have enhanced their conceptual understanding. Learners are more likely to participate actively in, and to enjoy science lessons if they direct their learning (Thornman & Phillips, 2001). In addition, the use of a TWBI approach, which provided authentic visualisations of Astronomy phenomena, might have made difficult and abstract Astronomy concepts more concrete to learners. The authentic visualization of phenomena provided by web-based instruction may not be achieved using textbooks. This assumption is in line with the views of Vosniadou and Brewer (1994), as well as those of Agan (2004), that learning Astronomy concepts from textbooks can create inadequate mental models in learners, which may lead to the development of misconceptions. In a study involving the use of web-based educational technologies to rectify identified Astronomy misconceptions, Gurbuz (2016) found that the majority of the teachers who did not initially have a normative understanding of basic Astronomy concepts improved their scores with the aid of a web-based instruction. Similarly, the authentic visualization provided by the TWBI used in this study could have assisted learners to transition from a naïve conception of celestial bodies to a more normative understanding of the concepts.

The qualitative data showed that participating learners had limited exposure to computers and the internet prior to the intervention, although the majority of them indicated that they were interested in using these devices for the purpose of teaching and learning. Failure to expose learners to web-based instruction is disheartening, given the fact that the world is now operating within the fourth industrial revolution, which is characterized by the use of computers and the internet for knowledge acquisition, especially in the context of education (NASA, 2006). Learners indicated that their involvement in the TWBI improved their comprehension of Astronomy concepts. This declaration is in line with findings from Chumley-Jones, Dobbie and Alford (2002), who analysed 20 studies, on the link between Web-based learning and knowledge acquisition, all of which revealed substantial gains.

Despite learners’ positive pronouncements about their comprehension of Astronomy concepts, some of them still could not differentiate between certain Astronomy concepts such as revolution and rotation. This could suggest a lack of proficiency in the language of instruction, which is English. This is particularly true for South African Grade 4 learners who transition from being taught in their native languages in the Foundation Phase, to being taught in English in Grade 4 (Pretorius, 2014; DoBE, 2011). Learners might therefore struggle to express themselves in English.
CONCLUSION

In conclusion, the TWBI used in this study enhanced learners’ understanding of Astronomy concepts, and they showed positive attitudes towards the instructional approach. We therefore recommend the use of TWBI by practicing teachers, especially when teaching Astronomy concepts in Grade 4. We also propose an investigation into the feasibility of using smartphones to implement TWBI in science classrooms, in order to take advantage of the widespread availability of cell phones and their frequent use by learners. Furthermore, we recommend a longitudinal study to explore the long-term effects of TWBI on learner achievement in Astronomy. Finally, a study on the effect of TWBI on male and female learners is necessary to determine whether the instructional approach has gender bias.

Acknowledgements

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REFERENCES

ABSTRACT
The integration of information and communication technologies (ICTs) into teaching depends on teachers’ viewpoints manifested as concerns. This paper investigates teachers’ concerns in selected Lesotho schools regarding the new reform namely, the integration of ICTs into physical science instruction. Data were collected from a random cluster sample using the stages of concern questionnaire with an 8-point Likert scale. Statistical analysis software (SAS) was employed to analyse the data to get the descriptive results and the ANOVA of the hypothesis. The percentile score for the informational self-concerns was the highest at 87.5. This demonstrates that the teachers were concerned about gaining knowledge of ICT integration. These teachers therefore require ongoing support providing more information on available ICTs and their potential to improve teaching.

Keywords: ICT integration, concerns-based adoption model, teachers’ concerns, physical science

INTRODUCTION AND BACKGROUND OF THE STUDY
The 21st century life is technology-driven resulting in complex learners with different demands from their teachers (Dass, 2014). The link between educational transformation and ICTs has been established in developed countries rather than in developing countries (Shahmir, Hamidi, Bagherzadeh, & Salimi, 2010). Learners need to harness the potential of ICTs in their learning because ICTs can improve the quality of education in a variety of ways (Alkahtani, 2016). However, the use of ICTs for teaching is restricted, even in schools where the ICT resources are available (Gur & Karamete, 2015). The majority of teachers use ICTs in a limited manner even though they have positive feelings towards ICTs’ ability to improve instruction (Aslan & Zhu, 2016). The use of complex e-learning software such as Moodle and Sakai, among others, is particularly low in developing countries because these forms of ICTs have quickly evolving digital characteristics that complicate their use (Sife, Lwoga & Sanga, 2007).

ICT infrastructure and training will not necessarily result in the actual usage of ICTs for teaching (Agyei 2013). However, insufficient planning and lack of understanding regarding what the implementation ICT integration involves, among others, may result in limited instructional use of ICTs (Sife et al., 2007). Other barriers to ICT integration into classroom practice include, among others, restricted time, lack of knowledge and confidence among teachers, as well as dearth of technological skills among learners (Alkahtani, 2016). Teachers’ lack of control over computer laboratories, particularly where computers are managed by external funders, can also be a challenge. For instance, the Khanya project in the Western Cape in South Africa was perceived to be controlling when and who should use the computer laboratory (Chigona, Chigona & Davids, 2014). It is imperative to investigate teachers’ concerns regularly to afford them with appropriate support.

In Lesotho, ICT integration into the general curriculum is a demand of the national ICT policy (Lesotho government, 2005). This policy has led to the localised Lesotho version of the International General Certificate of Secondary Education curriculum. The curriculum demands learners’ acquisition of technological and communication skills as they learn the content (Examinations Council of Lesotho, 2012). Although the teachers are expected to use ICTs for instruction, there is no clear guidance regarding how this expectation should be met. Lesotho’s infrastructure and accessibility to ICTs are also poor (UNESCO, 2016). As a result, the rate at which teachers integrate ICTs into teaching is low in Lesotho (Kalanda & De Villiers, 2013). However, cellular phone services have increased the telephone mass in Lesotho from 1% to 96% between the years 2000 and 2015, thus making cellular data services accessible to more people (Morgan-Jarvis, 2015). Teachers need to take advantage of the modern technologies that are brought by smart phones. This paper explores the
teachers’ concerns related to their response to this call of the curriculum for the integration of ICTs into instructional activities by testing the null hypothesis that: High school teachers in Lesotho do not have significant concerns regarding the integration and use of ICTs for teaching physical science. The paper is outlined into five sections namely the introduction, the theoretical framework, the methodology, the results and discussions, as well as the conclusions and recommendations.

THEORETICAL FRAMEWORK

We need to understand teachers’ personal attributes and motivational factors that influence those attributes when introducing ICTs in schools. This is because teachers’ perspectives regarding ICTs affect their acceptance and use of technology for teaching (Chigona et al., 2014). Fuller, Parsons and Watkins (1974) refer to these perspectives as concerns by which teachers indicate their requirements. These writers posit that concerns motivate the teachers’ choice of what they want to learn. As a result, the present study is based on the concerns-based adoption model (CBAM). This model was developed by Hall, Wallace and Dossett at the University of Texas-Austin in 1973, building on Fuller’s concerns theory (Centikaya, 2012).

CBAM was chosen on grounds of its popularity among studies which seek to promote and facilitate innovations from the personal standpoint (Sultana, 2015). It is essential to comprehend the individual aspect of the implementation process to minimise resistance towards innovations (Hall & Hord, 2011). CBAM also helps us to describe and evaluate the phases of improvement of teachers learning about ICT integration into the classroom. This is because CBAM views change as a process rather than a once-off occasion, which transpires gradually through different phases determined by one’s abilities and feelings, among other factors. Most importantly, CBAM warns us against the presupposition that use of an innovation is only two-fold (use and non-use) but argues that it is a multifaceted endeavour (Hall, 2010). Table 1 summarises the stages of concern.

Table 3: Stages of concern (Adapted from George, Hall & Stiegelbauer, 2006, p. 40)

<table>
<thead>
<tr>
<th>Stages of concern</th>
<th>Expression of concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Refocusing impact concerns</td>
<td>Knowing an alternative that has more potential than ICTs.</td>
</tr>
<tr>
<td>5. Collaboration impact concerns</td>
<td>Worrying about interaction with colleagues when using ICTs.</td>
</tr>
<tr>
<td>4. Consequence impact concerns</td>
<td>Worrying about the effect of ICTs on students.</td>
</tr>
<tr>
<td>3. Management task concerns</td>
<td>Worrying about how long it takes to learn about the new ICTs.</td>
</tr>
<tr>
<td>2. Personal self-concerns</td>
<td>The need to know of the influence of ICTs on one’s daily work.</td>
</tr>
<tr>
<td>1. Information self-concerns</td>
<td>The need to know more information about ICT integration.</td>
</tr>
<tr>
<td>0. Awareness (Unconcerned)</td>
<td>Complete lack of knowledge about ICT integration.</td>
</tr>
</tbody>
</table>

METHODOLOGY

We applied a quantitative approach, deductive post-positivism and descriptive non-experimental survey design. This approach allowed us to be objective, logical and systematic when testing the hypothesis while concentrating on the purpose of the study (Mulwa, Kyalo, Bowa, & Mboroki, 2012). The design enabled a large population of teachers to be explored through a sample because it is flexible and adaptable (Johnson & Christensen, 2014).

A table of random numbers was used to select a cluster sample of 23 of 138 schools offering physical science (Examinations Council of Lesotho, 2012; StatTrek, 2016). The final sample consisted of 76 teachers. The schools were selected from five of the ten districts of Lesotho, namely Mafeteng, Maseru, Berea and Leribe in the lowlands as well as Mokhotlong in the highlands. This sample was varied for a fair representation of the population at more reasonable costs and time (Creswell, 2013). The respondents filled an 8-point Likert
questionnaire consisting of 21 close-ended items covering their demographics and concerns on ICT integration into instruction (Hall, George & Rutherford, 1977). Weightings of the responses ranged from 0=Irrelevant to 7=Very true of me now. The questionnaires were personally delivered to the selected schools and then gathered after completion. Data were analysed using the statistical analysis software (SAS, 2013). This software has recently become popular in research related to ICT integration into teaching and learning (Alkahtani, 2016). Firstly, the frequencies of the responses to the biographical questions were calculated. Then, the description statistics were calculated for the mean scores. The respondents were categorised for each biographical variable because all the variables were categorical. The mean for the stages of concern of the demographic groups was contrasted through one-way analysis of variance (ANOVA). The sum score in question was the dependent variable whereas the stipulated biographical variable was the single factor in the ANOVA model.

The ethical clearance for this study was obtained from the University of the Free State. Permission to conduct this study was acquired in writing from the Ministry of Education and Training as well as the principals of participating schools. Participation was voluntary and informed. The respondents were not deliberately exposed to harm and their privacy and confidentiality were observed (Johnson & Christensen, 2014). A pilot study was conducted to enable the necessary amendments to the research process to be made for a higher response rate and stronger reliability and validity. Some of the confounding variables of the study, such as teachers’ age and gender, were explored in terms of their effect on the teachers’ concerns to improve internal validity (Bhattacherjee, 2012).

RESULTS AND DISCUSSIONS

Demographic results

Table 2 shows the demographic details of the sample. The sample was constituted by higher percentages of teachers aged 30 to 39 (53), males (69), teachers with 5 to 14 years of experience (51), teachers from church schools (81) and teachers from schools in the lowlands (89). The numbers of teachers in various categories differ because some of the teachers did not provide some of their demographic details.

<table>
<thead>
<tr>
<th>Age (n=73)</th>
<th>Gender (n=71)</th>
<th>Experience in years (n=72)</th>
<th>School type (n=73)</th>
<th>School location (n=72)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20-29</td>
<td>Male</td>
<td>0-4</td>
<td>Churc</td>
<td>Lowland</td>
</tr>
<tr>
<td>30-39</td>
<td>Female</td>
<td>5-14</td>
<td>Other</td>
<td>Highland</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>15</td>
<td>59</td>
<td>64</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td></td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>53%</td>
<td>26%</td>
<td>69%</td>
<td>89%</td>
</tr>
<tr>
<td></td>
<td>21%</td>
<td>31%</td>
<td>31%</td>
<td>11%</td>
</tr>
<tr>
<td>20-29</td>
<td>6%</td>
<td>28%</td>
<td>51%</td>
<td>89%</td>
</tr>
<tr>
<td>30-39</td>
<td></td>
<td></td>
<td>21%</td>
<td></td>
</tr>
</tbody>
</table>

Teachers’ stages of concern

The percentile scores for the stages of concern for all the teachers in the sample are 12.5, 87.5, 50, 25, 62.5, 75 and 37.5 for stages 0, 1, 2, 3, 4, 5 and 6 respectively. The teachers’ concerns are the most intense around stage 1 (informational concerns) and stage 5 (collaboration concerns), as it was the case in other studies (e.g. Centikaya, 2012; Lopez & Wise, 2014). George et al. (2006) posit that teachers with longer experience with an innovation typically have high collaboration concerns (stage 5). In the case of Lesotho, these may be the teachers who started using ICTs before the new curriculum was introduced or when it began in 2012, hence the experience with ICT integration into their instruction. Teachers who do not use ICTs, or those who are beginning to use them, are expected to have high informational concerns (Hall, Newlove, George, Rutherford, & Hord, 1991). More teachers were at stage 1 showing that they require information about ICTs. The combination of high informational and collaboration concerns is indicative of teachers considering the possibility of learning from each other regarding the integration of ICTs into the curriculum (Shu, 2016).
The percentile score for stage 0 is the lowest at 12.5 indicating that only a few teachers are not aware of the new innovation that demands ICT integration into curricular activities. Hall and Hord (2011) emphasise that many respondents will not be concerned about a reform that is only starting. Therefore, many teachers seem to be aware of the ICT-driven curriculum which commenced in 2012. The sampled teachers also had the second lowest percentile score (25) at stage 3 (management concerns), thus indicating that a relatively low number of teachers is concerned about time and administration issues involved in the learning of the new forms of technology (Hall et al., 1977). The percentile score for stage 6 (refocusing concerns) which is 37.5 is lower than the score for stage 5 (75) showing a downward ending of the results. This means that the teachers are uninformed of any other innovation that works better than ICT integration for instructional improvement (Hall et al., 1991).

Table 3 illustrates teachers’ mean and standard deviation scores according to their demographic groups. This table shows the stage 1 mean for teachers working in schools not owned by churches as 6.2 and for teachers working in the highlands as 6.4. These scores are higher than the overall mean score for all teachers which is 5.7 for stage 1. These teachers are relatively more curious about ICTs than the rest of the sample. This concern may be related to the availability of ICT resources for the selected government and community schools (others) as well as schools in the highlands (Hall et al. 1991). Table 3 also shows stage 5 mean scores as 5.0 for female teachers, 5.3 for teachers aged 20 to 29, 5.2 for teachers between 0 and 4 years of experience, 5.3 for teachers from government and community schools (others) and 5.4 for teachers from the highland schools. These groups have higher mean scores for collaboration concerns than the overall mean score for this stage, M=4.9. The teachers from schools in the highlands have a more interesting profile indicating the highest mean scores for all stages except for stage 4. This indicates that they have more intense concerns than the rest of the groups in general.

All the standard deviations range from 0.4 to 2.2 (see Table 3). These low standard deviations signal non-significant differences within the groups. However, the group of teachers with 15 or more years of experience has the highest standard deviations for stages 2 (2.0), 3 (1.7), 4 (2.0), 5 (2.1) and 6 (2.0) which demonstrate the largest variations within the group. These teachers seem to have different experiences regarding ICT training. Some of them may have obtained some ICT skills from teacher workshops and self-training initiatives (Khan, 2014).

Table 5: Descriptive statistics of teachers’ stages of concern by biographical groups

<table>
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<td>5.4</td>
<td>0.8</td>
<td>5.3</td>
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</table>
Reliability
The Cronbach alpha coefficients of internal reliability for the stages of concern were 0.63_0, 0.62_1, 0.43_2, 0.34_3, 0.55_4, 0.68_5 and 0.27_6. These values are not comparable with the values obtained by Hall et al. (1977) where n=830. Their large sample size may have caused their alpha values’ to range from 0.64 to 0.83. However, the coefficients are comparable to George et al.’s (2006) values from their validity study where n=40. This sample size was small and the alpha values ranged from 0.41 to 0.69. Our coefficients indicate that the items used were nonetheless reliable because they were neither above 0.9 nor very close to 0 (Tavakol & Dennick, 2011).

ANOVA for the hypothesis
Most of the p-values (32 of 35) for the stages of concern (Table 4) are above the statistical significance level (α) of 0.05 (Bhattacherjee, 2012). Consequently, we fail to reject our null hypothesis that high school teachers in Lesotho do not have significant concerns regarding the integration and use of ICTs for teaching physical science. The results do not seem to depend on the teachers’ age, gender, experience, type or location of school. However, there are three (of 35) p-values below the confidence level, α = 0.05. These are the values for gender (p = 0.0143_2 and p = 0.0087_6) and for type of school (0.0066). These three values demonstrate significant differences between the intensity of concerns between males and females related to how the use of ICTs will affect their daily routine in stages 2 and their knowledge of other innovations that work better than ICTs in stage 6. They also mean that there is a significant difference between teachers working in church schools and other schools regarding how the ICTs impact on their students in stage 4 (Greenland et al., 2016). The sources of the differences between these groups of teachers require further research.

### Table 6: The p-values for the stages of concern

<table>
<thead>
<tr>
<th>Stage of concern</th>
<th>Age</th>
<th>Gender</th>
<th>Experience</th>
<th>Type of school</th>
<th>Location of school</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-Awareness</td>
<td>0.2280</td>
<td>0.8826</td>
<td>0.7397</td>
<td>0.7818</td>
<td>0.2685</td>
</tr>
<tr>
<td>1-Informational</td>
<td>0.8526</td>
<td>0.7714</td>
<td>0.7178</td>
<td>0.1757</td>
<td>0.2339</td>
</tr>
<tr>
<td>2-Personal</td>
<td>0.1111</td>
<td>0.0143</td>
<td>0.7125</td>
<td>0.6726</td>
<td>0.7935</td>
</tr>
<tr>
<td>3-Management</td>
<td>0.4532</td>
<td>0.0937</td>
<td>0.8749</td>
<td>0.3111</td>
<td>0.1610</td>
</tr>
<tr>
<td>4-Consequence</td>
<td>0.1284</td>
<td>0.1211</td>
<td>0.5422</td>
<td>0.0066</td>
<td>0.9046</td>
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<tr>
<td>5-Collaboration</td>
<td>0.3766</td>
<td>0.7349</td>
<td>0.2720</td>
<td>0.4173</td>
<td>0.6114</td>
</tr>
<tr>
<td>6-Refocusing</td>
<td>0.2122</td>
<td>0.0087</td>
<td>0.5629</td>
<td>0.0948</td>
<td>0.2074</td>
</tr>
</tbody>
</table>

CONCLUSIONS AND RECOMMENDATIONS
In most countries, including Lesotho, it is the government officials’, rather than teachers’ decision to choose to use various ICT resources in schools (Hall, 2010). Research affords decision makers with the necessary information for planning future reforms and monitoring progress of their implementation (Hall & Hord, 2011). Evidence from studies on teachers’ concerns may lead to a tailored support for the teachers.

This article sought to establish the teachers’ concerns regarding the integration of ICTs into the teaching of physical science. The sampled physical science teachers experienced the entire spectrum of concerns from stage 0 to stage 6. However, the results demonstrate that most teachers have informational self-concerns (stage 1), which are typical of people either at an early phase of an innovation or who do not use the innovation (George et al., 2006). The physical science teachers are willing to integrate ICTs into their instruction even though they may not be currently doing so for reasons that require further inquiry. A good number of teachers also reported impact concerns in stages 4 and 5. As Hall et al. (1991) have asserted, a profile that peaks around these stages befits teachers with plenty of experience with the innovation. These teachers are interested in learning from their colleagues and they are also curious about how ICT impacts student learning.
These findings should be used with caution because the sample was not large enough to reach the targeted 50% of the 138 schools that offer physical science, which is recommended for the results to be generalised to the rest of the population (Leedy & Ormrod, 2005). However, the results are useful because the sample was representative of most groups of teachers. We recommend that teachers’ needs related to ICT integration into the curriculum should be thoroughly interrogated through research in order for them to be incorporated into the future educational plans.

REFERENCES


PRESERVICE TEACHERS’ REFLECTIONS ON TEACHING SCIENCE WITH PRACTICAL WORK IN MULTIPLE-DEPRIVED CLASSROOMS
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ABSTRACT – Practical work is central to science education because it has several affordances for teaching and learning. Preservice science teachers may learn to facilitate practical work in schools during teaching practice. However, it is important for teacher training programmes to establish what the preservice science teachers learn about teaching science with practical work in the schools. Most of the science classrooms in the schools are characterised by challenges that result in conditions of multiple-deprivation for teaching and learning. Using a pedagogical content knowledge conceptual framework for science teaching, this study explored the teaching of science with practical work in schools through the reflections of five final year preservice physical sciences teachers at one South African university. In a qualitative case study of teaching science with practical work in multiple-deprived classrooms, purposive sampling was used to select the preservice science teachers. The data collection tools were the preservice teachers’ reflection journals completed during practicum. The preservice teachers reflected on how science was taught with practical work in the multiple-deprived classrooms and on how they could improve the practices. Findings point to reflection as a potentially powerful tool for preservice science teachers to develop positive attitudes and perceptions on key aspects of the pedagogical content knowledge for science teaching with practical work. In addition, the study identifies knowledge and beliefs of science classroom contextual settings as aspects of the pedagogical content knowledge for science teaching with practical work. Recommendations for practice are made.

Keywords: multiple-deprived classrooms; practical work; preservice teachers; teaching science; reflections

INTRODUCTION
Practical work activities are inherent in school science curriculums. However, teachers are generally reluctant to teach science with practical work due to a number of factors (Kim & Tan, 2011). Some of the known factors that discourage teachers are time constraints, lack of materials, curriculum demands and limited teacher pedagogical content knowledge. In this paper, I posit that the factors discouraging teachers to teach science with practical work create multiple-deprived classrooms. Multiple-deprivation is a social condition resulting from an accumulation of single domains of unmet needs (Noble, Zembe, Wright & Avenell, 2013). Ramnarain (2014) studied multiple-deprived conditions for inquiry science learning in South Africa. The findings indicate that teacher-centred instructional strategies, large classes, lack of resources and absence of inquiry-based learning characterise multiple-deprivation. These conditions were more pronounced in township and rural schools. Preservice science teachers are expected to experience similar conditions in their future classrooms. Accordingly, teacher-training programmes should strive to prepare preservice science teachers for practical work facilitation in all school contexts to avoid the creation of multiple-deprived classrooms for practical work. Teacher training programmes need to be sensitive to preservice science teachers’ experiences in teaching science through work-integrated learning (teaching practice). Preservice teachers’ teaching practice experiences may be used as data to improve teacher-training practices for science teaching with practical work. One way of collecting data on preservice teachers’ experiences of opportunities to learn during teaching practice is through eliciting their reflections. The research question for the study is: How do preservice science teachers learn to teach science with practical work in multiple-deprived classrooms through their reflections of teaching practice experiences?

THEORETICAL BACKGROUND
Practical work is pivotal in science education. It can be used as an instructional strategy to facilitate the learning of scientific knowledge (Millar, 2004). In addition, it forms part of the scientific knowledge that is learnt through other instructional strategies. Wei and Liu (2018) point out that, teachers through demonstrations and experiments by learners, can facilitate practical work. However, Millar (2009) explains that practical work activities vary in nature by
what they ask learners to do and what they try to teach to learners. The activities may also vary in complexity from simple theory confirmation to open-ended investigations. The Department of Basic Education (2011, p. 11) echoes this when it says: “Practical work must be integrated with theory to strengthen the concepts being taught. These may take the form of simple practical demonstrations or even an experiment or practical investigation.” Practical work may also be used to achieve other broader science education goals such as the development of inquiry skills in learners. The result is a growing list of instructional strategies for practical work. Inquiry-based practical work is one example of an instructional strategy in tandem with inquiry-based science as a broad science educational goal. It can be safely concluded in this section that science teachers and preservice teachers alike need to develop significant knowledge in order for them to be able to teach science with practical work. This significant knowledge also needs to be adapted to a variety of schooling contexts including the multiple-deprived classrooms. Consequently, this study uses a pedagogical content knowledge lens to explore the knowledges of teaching science with practical work in multiple-deprived classrooms through preservice teachers’ reflections.

**Conceptual framework**

The pedagogical content knowledge (PCK) concept by Shulman (1987) is applicable to a wide range of classroom situations to explain teacher knowledge. The PCK concept has received significant research attention that forms the basis for further conceptualisations of teacher knowledge. A case in point is the topic-specific pedagogical content knowledge (TSPCK) by Mavhunga and Rollnick (2016). The implication is that whilst teachers are required to possess significant PCK to be professionals, they are also expected to possess specialised PCK concomitant with the subjects they teach and the different topics in the subject areas. Significantly, the development of PCK for science teaching is very important for those who aspire to be science teachers. Grossman (1990) and Magnuson, Krajcik and Borko (1999) formulated five key aspects of PCK for science teaching. First, teachers display particular orientations when teaching science. Second, teachers possess varying degrees of knowledge and beliefs about learners’ understanding of specific science topics. Third, teachers possess knowledge and beliefs about the science curriculum. Fourth, teachers possess knowledge and beliefs about instructional strategies for teaching science. Fifth, teachers possess knowledge and beliefs about assessment in science. The use of TSPCK results in operationalising teacher knowledge in terms of practical work. In this study and as suggested in Wei and Liu (2018), teacher knowledge for practical work has been adapted accordingly. The five teacher knowledge domains used are (i) orientations for practical work, (ii) knowledge and beliefs about learners’ understanding of practical work, (iii) knowledge and beliefs about the practical work curriculum, (iv) knowledge and beliefs about instructional strategies for practical work, and (v) knowledge and beliefs about the assessment of practical work. This framework for PCK will be used to make sense of teaching science with practical work through the preservice science teachers’ reflections.

**STUDY CONTEXT AND DATA COLLECTION**

This study was conducted as a qualitative case study. Creswell (2007) defines a case study as a bounded system defined by particular parameters. In light of this, the phenomenon explored in this study defined the case. The phenomenon explored was the preservice science teachers’ perceptions of teaching science with practical work in multiple-deprived classrooms. The study was designed around a final year preservice teachers’ Bachelor of Education (Bed) physical science teaching practice course at one university in South Africa. The teaching practice course lasted for 14 weeks. During the teaching practice, the preservice science teachers had opportunities to plan lessons and teach secondary school learners (Grades 8-12). The preservice teachers also had opportunities to learn from teacher mentors through lesson observation and other relevant activities. Purposive sampling ensured that the selected preservice teachers were in schools with multiple-deprived science classrooms. The schools were all situated in rural parts of QwaQwa in the Free State Province of South Africa. The participating preservice teachers were provided with a semi-
structured reflection guide before they left for teaching practice. The reflection guide ensured that the preservice teachers documented the school and classroom contextual settings with the aim of describing the conditions of multiple-deprivation. The guide also enabled them to describe the teaching of science with practical work in the classrooms. They noted the instructional strategies used for teaching science with practical work. The participants were also asked to freely critique the lessons taught in terms of strengths and weaknesses. Finally, they were asked to describe how they could improve the lessons if they were to conduct them in future. The study was part of a larger, design-based study that had already been ethically cleared by the university and the reflection guide was one of the assessment tools used by the methods course to assess the preservice physical sciences teachers during practicum. Therefore, permission was sought from the purposively selected sample of participants to use their reflections.

Participants
The participants were five final year preservice physical science teachers from a 4-year BEd programme. The students were assigned pseudonyms PPT 1-5 (Physical sciences preservice teacher 1-5). The participants were invited through a call made by the researcher that asked for permission to use their reflections for this study. Twenty students consented to participate in the study. However, five participants were selected after an analysis of their reflections. The selected reflections met the requirements of purposive sampling in which practical work was conducted in multiple-deprived classrooms. The multiple-deprivation conditions relevant included shortages of materials for practical work implementation and negative teacher attitudes towards the use of practical work. The reflections in which the preservice teachers considered the use of practical work effective were avoided.

Data analysis
Thematic analysis, using directed content analysis, was used to organise the findings into five themes in relation to the reflection instrument. The themes were (i) conditions of multiple deprivation identified by the preservice teachers, (ii) how science was taught with practical work, (iii) nature of practical work used to teach science, (iv) improvisation strategies in multiple deprived classrooms, and (v) preservice teachers’ suggestions to improve practical work facilitation. The preservice teachers were required to write their reflections under each of those guiding themes. The themes also guided data analysis and presentation.

Results
The most representative excerpts from the five preservice physical sciences teachers were used under each theme. The researcher did not see the need to write down the reflections of all the five preservice teachers if they were repetitive.

Conditions of multiple-deprivation identified by the preservice teachers
The preservice teachers highlighted time constraints and the lack of materials as major challenges in the multiple-deprived classrooms. PPT5 said, “Due to time and unavailability of materials we didn’t do some of the practical work activities, because when we were busy choosing materials that we needed to replace or checking for materials. It consumes time so we ended up not having enough time to perform practicals.” Time constraints also came up as one of the conditions experienced in the multiple-deprived classrooms. In addition, PPT2 said, “The class had a large group of learners, and the materials were limited. The teacher had to divide the class into groups of 10. Not all the materials were available in the lab. The teacher had to buy some of them, from his own pocket; things like cooking oil, acetone -and glycerine.” In confirmation of what PPT2 said, “I could see that some of the classrooms were overcrowded and the teachers had to go an extra mile by using their personal money to buy some of the materials.”

How science was taught with practical work
I selected reflection excerpts from PPT1, PPT2 and PPT4 that summarised how science was taught with practical work in the multiple-deprived classrooms. First, in some instances the teachers just described the experiments and the expected results to the learners. PPT1
confirmed: “We just went through the procedure and steps in the textbooks and constructed the experiment in our mind and suggested the possible results especially on distillation and filtration.” Second, some of the practical work activities were facilitated for the learners. As reported by PPT2, the teachers were demotivated by the conditions of multiple-deprivation in the classrooms. PPT2 said, “Only 3 activities were implemented without any challenges, the 4th experiment could not be implemented because of the lack of motivation on the teacher’s part and the materials were not available; those that were available were outdated.” Third, whilst PPT4’s reflection corroborated what PPT1 and PPT2 had said, he added that teachers sometimes showed learners videos of the experiments. PPT4 said, “For the practical work activity that was not implemented I think, the teacher was pressed for time and because he felt that is a repetition of the ones he had done already. The teacher showed the learners a video demonstration of the practical work.” Practical work was also in the form of demonstrations and required learners to record the observations. PPT5 said, “Since we had limited materials every learner observed as the teacher demonstrated and followed the procedure step by step. They recorded every observable change during the experiment demonstration, for instance where ice was heated to gas (water vapour) and they had to record temperatures of the solid, liquid and gas states.”

Nature of practical work used to teach science
The practical work activities described by the preservice teachers were conducted as experiments. PST4 said, “Scientific method[s] where learners had to construct their own hypothesis and construct the experiment were used.” There was no indication of any other form of practical work besides the experiments from all the five PPTs. However, the learners had some experiences of the nature of science.

Improvisation strategies in multiple-deprived classrooms
The preservice teachers’ reflections also showed that the teachers found ways of improvising when materials for certain practical work activities were lacking. PPT5 affirmed: “We had to replace unavailable materials with relevant available materials; for a burner we used candles and for a tripod we used bricks and a gauze, and for a petri-dish we used the lid of Frisco tin. It was a stupid idea, but at the end learners understood and they were able to check whether their hypothesis was accepted or rejected.” Initially, the preservice teacher considered that improvisation of materials may not quite serve the purpose effectively, however in this case she subsequently realised that it did. Videos were also used in place of actual hands-on practical work activities. PPT3 said, “The practical work was not implemented due to shortage of materials and equipment to perform the experiments so my mentor teacher would first look for a related topic with the practical [work] on the internet and I downloaded the video then I took it to the school library projector and connected it to the classroom with power. I called the learners to watch the video for them to get some understanding of what was expected of them when answering questions about the practical activity.” These videos were just for learners to watch and not for the learners to manipulate variables.

Preservice teachers’ suggestions to improve practical work facilitation
The preservice teachers thought that teachers could use other resources outside the school to ensure that learners were exposed to practical work facilitation. PPT1 said, “Since there are centres of Maths, sciences and technology I will plan a trip where learners will have a chance to conduct different experiments and they will have time to ask questions and construct their own understanding from the facilitators at the centre. They will also be given a chance to conduct at least two of the experiments on their curriculum.” The preservice teachers believed that teachers should be able to identify household materials that could be used to replace some of the prescribed materials for practical work activities. They also thought that the use of videos by both teachers and learners could help them to see how some practical work activities should be conducted before they engaged in hands-on activities. They also felt that the teachers should attend workshops on how to teach science with practical work. PPT2 summed up the role of the workshops when she said: “To teach them to improvise, to look for and find the appropriate materials that are used in households
e.g. acetone for nail polish remover and to use them as substitute materials. They should give them in-depth content and knowledge about the subject matter. They should be made to watch exactly the same video of the practical work so they know how to conduct it themselves. By doing thorough research about the topic that is troubling, by workshopping them on the how to deliver them and then make them conscious of the importance of practical work in teaching and learning.”

**DISCUSSION AND CONCLUSION**

The study set out to explore how preservice teachers learn to teach science with practical work in multiple-deprived classrooms through their reflections of teaching practice experiences. On comparing the conceptual framework for the study, which is PCK for practical work (Wei & Liu, 2018) with the findings it can be concluded that the preservice teachers gained some forms of knowledge and beliefs of teaching science with practical work in multiple-deprived classrooms. As a science teacher educator, I took note of what they learnt and what they were not able to learn from the teaching practice experiences. The preservice teachers could develop both positive and negative attitudes and perceptions in teaching science with practical work. First, of the forms of practical work, the preservice teachers learned to facilitate experiments. They did not mention other types of practical work. The perception developed out of this experience could be negative because it can limit their knowledge of practical work. Second, the preservice teachers their mentors in the multiple-deprived classrooms improvise when prescribed materials for practical work were not available. This observation created a positive perception that it is possible to facilitate practical work for learners in classrooms that lack materials. Third, the preservice teachers also observed the in-teachers failing to facilitate practical work activities for learners. However when asked how practical work facilitation could be improved in multiple-deprived classrooms, the preservice teachers understood that something could be done and they were able to provide alternative ways of ensuring that science was taught with practical work for learners. In conclusion, this study identifies a form of knowledge in addition to the PCK already defined in literature for teaching science with practical work. In addition to the teacher knowledge and beliefs for science teaching (Grossman,1990 & Magnuson et al.,1999) and accordingly, knowledge and beliefs for practical work (Wei & Liu, 2018) which are the five knowledges discussed under the conceptual framework section above, preservice teachers also developed knowledge and beliefs for teaching science in multiple-deprived classrooms. The preservice teachers developed knowledge for classroom settings that influenced the decisions they made for teaching and learning. Hence, this study contends that knowledge and beliefs for science classrooms’ contextual settings (multiple-deprived or not) are part of the knowledges that the preservice science teachers should develop. The knowledge should include how practical work can be implemented under different classroom settings. This knowledge should be augmented by the knowledge of different ways to conduct practical work in science so that the teachers’ perceptions of practical work are not limited to experiments. Knowing the different forms of practical work would assist the teachers to provide alternative practical work activities in different classroom settings. In addition, the study recommends that, preservice teachers’ reflections of practicum experiences can be used as a form of feedback of the experiences and learning opportunities for preservice science teachers on teaching strategies such as practical work. The reflections can be used as a feedforward for subsequent preservice science teacher preparation.

**ACKNOWLEDGEMENTS**

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Millar, R. (2009). *Analysing practical activities to assess and improve effectiveness: The Practical Activity Analysis Inventory (PAAI)*. University of York: Centre for Innovation and Research in Science Education, Department of Educational Studies


ACTIVE LEARNING STRATEGIES AS DETERMINANTS OF PRE-SERVICE BIOLOGY TEACHERS’ LEARNING OUTCOMES
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Adeyemi College of Education, Nigeria
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ABSTRACT
Available data showed that pre-service biology teachers at Colleges of Education in South-western Nigeria have low achievement in and exhibit negative attitude to population education. Previous studies largely focused on teachers and students’ attitude to population education with minimal emphasis on intervention through group-based interactive learning strategies. This study, therefore, determined the impact of Team-Based Learning Strategy (TBLS) and 5E Learning Strategy (5ELS) on pre-service biology teachers’ achievement in and attitude to population education. The moderating effect cognitive ability was also examined. Theory of Positive Social Interdependence provided the framework, while the pre-test post-test control group quasi experimental design was adopted. An intact class of second year pre-service biology teachers from three federal colleges of education was randomly assigned to TBLS (171), 5ELS (90) and Control (140) groups. Instruments used were PEAT (r=0.80), PTCAT (r=0.81) tests, PEAS (r=0.82) questionnaire, and Instructional Guides. Data were analysed using Estimated Marginal Means, ANCOVA and Bonferroni post-hoc test at 0.05 level of significance. There was significant effect of treatment on achievement (F(2,378)=12.26; partial η2=0.06), also on attitude (F(2,378)=27.90; partial η2=0.13). There was a significant effect of cognitive ability on pre-service biology teachers’ attitude (F(2,378)=3.2; partial η2=0.02). There was a significant interaction effect of treatment and cognitive ability (F(4,376)=2.44; partial η2=0.03) on achievement in favour of high cognitive ability pre-service biology teachers from 5E group. Employing these two strategies to teach population education would be a strategic means of developing and improving pre-service biology teachers’ ability to retain, construct and reconstruct knowledge from learning experiences. This also would help them to solve population issues whether personal or communal within and outside of the classroom.

Key words: Active learning strategies, population education, pre-service biology teachers, attitude and achievement

INTRODUCTION
In Nigeria’s Colleges of Education, there are compulsory courses in biology such as population education, which pre-service biology teachers must offer and pass before they can be certified as Nigeria Certificate in Education (NCE) holders. Population education is multidisciplinary as it draws its content from, and, cuts across a wide range of other subject disciplines such as basic science, biology, social studies, health education, environmental education, population and family life education (Pop/FLE), family life and HIV education, family life and health education (FLHE), demography, geography, urban and regional planning and others.

One identified major problem militating against the effective teaching of courses in Nigeria’s tertiary institutions is the use of conventional lecture strategy adopted by lecturers to teach (Aremu & Salami, 2013; Agoro, 2012). However, one germane reason for this could be due to the huge growth in knowledge in many areas of biological sciences which has created a untold confusion for lecturers in tertiary institutions, for not only must they transmit new facts and concepts to their students, they must also ensure that they comprehend and appreciate them (Mulley, 2015).

A critical look at the performance (Table 1.1) in the three colleges during the years under review revealed low achievement as a whopping 1527 (55.8%) candidates of the total 2736 performed below average; they failed to score 50 marks out of the maximum obtainable 100 marks. This calls for concern if the objectives of including population education in the curriculum of pre-service biology teachers are to be achieved. Also, studies (Medhi, 2017; Monika, 2013; Kavita, 2002) have revealed that school teachers have poor knowledge of, and, exhibit negative attitude to population education. Implication of this problem could be that learners under the tutelage of these teachers would likely not fare any better because they would neither be taught beyond their teachers’ knowledge nor encouraged to exhibit attitude better than their teachers.
Puerta (2015) in a study established a significant relationship between cognitive processes and academic performance. Despite the fact that cognitive abilities have been studied and linked to academic achievement, research continues to display gaps in the understanding and exploration of students' cognitive abilities (Finn et. al., 2013). Also, there is little research on cognitive ability which focuses on the tertiary level (Loveland, 2014).

**OBJECTIVE OF THE STUDY**

This study focused on adopting active learning strategies such as team-based and 5E strategies to remediate the performance deficiencies of pre-service biology teachers in, and negative attitude to population education in Colleges of Education in Southwest, Nigeria.

**RESEARCH HYPOTHESES**

H01: There is no significant effect of treatment on pre-service biology teachers’ achievement in population education

H02: There is no significant effect of treatment on pre-service biology teachers’ attitude to population education.

H03a: There is no significant interaction effect of treatment and cognitive ability on pre-service biology teachers’ achievement in population education

H03b: There is no significant interaction effect of treatment and cognitive ability on pre-service biology teachers’ attitude to population education

**THEORETICAL FRAMEWORK: Theory of positive social interdependence**

Though there are at least four major theories supporting the use of cooperative learning, social interdependence theory stands out as the most useful and influential theory underlying cooperative learning (Johnson and Johnson, 2015). Positive interdependence is an element of cooperative and collaborative learning where members of a group who share common goals perceive that working together is individually and collectively beneficial, and success depends on the participation of all the members (Johnson, Johnson and Holubec, 1998; Choi, Johnson and Johnson, 2011). Positive social interdependence is the first important element for a rewarding team-learning with combined rewards, shared resources, and supportive roles (Johnson, Johnson, and Holubec, 1998) but the success of one member is dependent on the success of the entire members of the team (Laal, 2013). The positive social interdependence theory is relevant and applicable to the TBL and 5E strategies as students work together cooperatively, cohesively, sharing knowledge, views and opinions with the goal of reaching a consensus decision. In the two strategies, students depend on one another for the successful completion of tasks or assignments culminating in positive interdependence.
LITERATURE

Attitude and academic achievement are significant factors in ensuring students’ success in science (Hussaini, Foong & Kamar, 2015; Kay & Geban, 2011). Studies on the link between attitude and academic achievement have found that these two variables were closely related to each other (Kurbanoğlu & Akin, 2010) while Hofstein & Mamlok-Naaman (2011) affirmed that students’ disposition to science subjects is hinged on the level of their active involvement and participation in the instructional process. These submissions probably informed the suggestion of Khan & Ali (2012) that understanding students' attitude is crucial in reinforcing their achievement and interest towards a specific discipline.

Cognitive ability is another strong prognosticator of students' academic achievement (Deary et al., 2007) which Philipson and Philipson (2012) described as students' ability to carry out advanced mental processes that border on critical thinking, comprehension, and proffering solutions to problems. Cognitive abilities are neuron-dependent skills essential to execute any assignment from the easiest to the most difficult (Michaelon, 2006). These skills provide the most frugal and straight-to-point explanation that predict academic performance both by purpose and verifiable support (Loveland, 2014). For students to develop and use these skills, a call for a shift in pedagogical paradigm has been made by the Federal Republic of Nigeria (FRN) that, educational activities shall be learner- centred, teaching shall be practical, activity-based, and experiential (FRN, 2014). Despite this call, lecturers do not always employ strategies that can help improve pre-service teachers' cognitive ability thereby making them often times struggle to apply the knowledge learned to later classroom practice (Schafer, 2014). Though a lot of studies had been carried out to establish that cognitive ability can be used to forecast academic performance of students, little of this focused on the tertiary level (Loveland, 2014).

The use of active-learning strategies acknowledges the fact that learning is a spectacle of the human brain, and that the individuals engaged in learning must be actively involved in constructing meaning, assessing their prior ideas, and resolving misconceptions (Miller & Tanner, 2015). Scholars (Brame, 2016; Nelson & Crow, 2014; Eison, 2010) have established that adopting active-learning strategies could bring about enhanced student attitude and learning outcomes. Hence, this study considered Team-Based and 5E (Engage, Explore, Explain, Elaborate, Evaluate) learning strategies which are constructivist-based and have been proved by scholars to encourage students’ active participation, engagement and involvement, self-directed learning, collaboration, and most importantly, application of knowledge to solving problems inside and outside of the classroom.

Team-Based Learning (TBL) is a tutor-directed strategy that incorporates multiple small groups in a single classroom (Middleton-Green & Ashelford, 2013), a pedagogy that facilitates students working collaboratively as teams to learn a subject (St Clair & Chihara, 2012) and encourages development of higher cognitive skills such as application, analysis and evaluation (Imazeki, 2015). However, Whitaker (2011) observed that there is very little evidence of the use of Team Based Learning Strategy (TBL) in undergraduate teacher preparation despite its potential to moderate the negative effects of large class size and limited time.

Another active learning strategy this study employed is the 5E Learning (5EL). There are five phases and each has a definite role which supports the instructor’s presentation of lessons and enables students to analyse and integrate current information in activity-based classes (Puteh & Nawastheen, 2013). The 5E strategy according to Warner and Myers (2013) shares features with guided discovery and teachers can use it to meet objectives and deliver specific concepts and explanations. A core benefit of 5E aside other benefits linked to constructivist approaches to instruction is making learning opportunities available for students (Moyer, Hackett & Everett, 2007). This study considered Team-Based Learning Strategy (TBL) and 5E Learning Strategy to address the aforementioned gaps.
RESEARCH METHODOLOGY

The study employed the pre-test post-test control group quasi experimental design. Variables considered in the study are: One independent variable (Instructional strategy) at three levels - Team-Based Learning Strategy (TBLS), 5E Learning Strategy (5ELS), and Conventional Strategy (CSIG), one moderator variable (Cognitive Ability) and two dependent variables (Achievement and Attitude). Purposive sampling of three Federal CoEs was based on availability of teaching/learning facilities and uniformity in academic calendar. An intact class of second year pre-service biology teachers from each college was randomly assigned to TBLS (171), 5ELS (90) and Control (140) groups. Instruments used were Population Education Achievement, PEAT (r=0.80), Pre-service Teachers Cognitive Ability, PTCAT (r=0.81) tests, Population Education Attitude Scale, PEAS (r=0.82) and three Instructional Guides- TBLSIG, 5ELSIG and CSIG. The PEAT and PEAS were developed by the researcher while PTCAT was adopted but modified from that developed originally by Newton and Bristoll (2009). The Instructional Guides were prepared by the researcher using the approved format for pre-service teachers’ Teaching Practice (TP) as a guide. All instruments were administered on a non-participating government-owned College of Education to ensure their validity and reliability. KR-20 was used to establish the reliability coefficient of PEAT while Cronbach Alpha was used for PEAS. The Instructional Guides were given to lecturers handling Population Education course in two Colleges of Education for face and content validity. Participants in the two intervention strategies were put into groups of 5-7 members using their class list to prevent subjective grouping. Treatment lasted ten weeks: one week for pre-test, eight weeks for treatment and one week for post-test. Data collected were analysed using Estimated Marginal Means, Analysis of Covariance, and Bonferroni post-hoc test at 0.05 level of significance.

RESULTS

Ho1: There is no significant effect of treatment on pre-service biology teachers’ achievement in population education

Table 7.1: Analysis of Covariance (ANCOVA) of Post-Achievement by Treatment and Cognitive Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial η Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1510.967</td>
<td>24</td>
<td>62.957</td>
<td>3.751</td>
<td>0.000</td>
<td>0.193</td>
</tr>
<tr>
<td>Intercept</td>
<td>9527.818</td>
<td>1</td>
<td>9527.818</td>
<td>567.687</td>
<td>0.000</td>
<td>0.602</td>
</tr>
<tr>
<td>Pre-Achievement</td>
<td>0.009</td>
<td>1</td>
<td>0.009</td>
<td>0.001</td>
<td>0.982</td>
<td>0.000</td>
</tr>
<tr>
<td>Treatment</td>
<td>411.445</td>
<td>2</td>
<td>205.723</td>
<td>12.257</td>
<td>0.000*</td>
<td>0.061</td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>13.871</td>
<td>2</td>
<td>6.936</td>
<td>0.413</td>
<td>0.662</td>
<td>0.002</td>
</tr>
<tr>
<td>Treatment x Cognitive ability</td>
<td>270.966</td>
<td>4</td>
<td>67.742</td>
<td>4.036</td>
<td>0.003*</td>
<td>0.041</td>
</tr>
<tr>
<td>Error</td>
<td>6310.629</td>
<td>376</td>
<td>16.784</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>262261.000</td>
<td>401</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>7821.596</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R Squared = .193 (Adjusted R Squared = .142) * denotes significant difference at 0.05

Table 7.1 shows that there is significant main effect of treatment on pre-service teachers’ achievement in population education (F(2,378) = 12.257; p<0.05, partial η² = 0.061). The effect size is 6.1%. This means that the significant difference in the post-achievement scores of pre-service teachers in population education was due to the treatment. Thus, hypothesis 1a was rejected. To decide on the magnitude of the significant effect across treatment groups, the Estimated Marginal Means of the treatment groups were carried out and the result is presented in Table 7.2.
Table 7.2: Estimated Marginal Means (EMM) for Post-Achievement by Treatment and Control Groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Based Learning Strategy (TBLS)</td>
<td>24.73</td>
<td>0.528</td>
<td>23.693 - 25.770</td>
</tr>
<tr>
<td>5E Learning Strategy (5ELS)</td>
<td>28.69</td>
<td>0.789</td>
<td>27.143 - 30.245</td>
</tr>
<tr>
<td>Conventional Strategy (CS)</td>
<td>23.77</td>
<td>0.594</td>
<td>22.599 - 24.933</td>
</tr>
</tbody>
</table>

Table 7.2 reveals that the pre-service teachers in 5ELS had the highest adjusted post-achievement mean score in population education (28.69), followed by TBLS Group (24.73), while the Conventional Strategy (CS) control Group had the least (23.77).

Table 7.3: Bonferroni Post-hoc Analysis of Post-Achievement by Treatment and Control Groups

<table>
<thead>
<tr>
<th>(I) Treatment</th>
<th>(J) Treatment</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower Bound - Upper Bound</td>
</tr>
<tr>
<td>Team-Based Learning Strategy</td>
<td>5E Learning Strategy</td>
<td>-1.4632*</td>
<td>.53280</td>
<td>.019</td>
<td>-2.7444 - .1819</td>
</tr>
<tr>
<td>Conventional Strategy</td>
<td>-2.5083*</td>
<td>.46632</td>
<td>.000</td>
<td>1.3869 - 3.6296</td>
<td></td>
</tr>
<tr>
<td>5E Learning Strategy</td>
<td>Team Based Learning Strategy</td>
<td>1.4632*</td>
<td>.53280</td>
<td>.019</td>
<td>1.1819 - 2.7444</td>
</tr>
<tr>
<td>Conventional Strategy</td>
<td>3.9714*</td>
<td>.55277</td>
<td>.000</td>
<td>2.6422 - 5.3007</td>
<td></td>
</tr>
<tr>
<td>Conventional Strategy</td>
<td>Team Based Learning Strategy</td>
<td>-2.5083*</td>
<td>.46632</td>
<td>.000</td>
<td>-3.6296 - 1.1819</td>
</tr>
<tr>
<td>5E Learning Strategy</td>
<td>-3.9714*</td>
<td>.55277</td>
<td>.000</td>
<td>-5.3007 - 2.6422</td>
<td></td>
</tr>
</tbody>
</table>

*denotes significant difference at 0.05

Table 7.3 reveals that the post-achievement mean scores in population education pre-service biology teachers exposed to 5ELS were significantly different from their counterparts in TBLS and CS. This shows that both 5E and team based learning strategies were the main sources of significant differences in treatment.

Ho2: There is no significant effect of treatment on pre-service biology teachers' attitude to population education

Table 7.4: Analysis of Covariance (ANCOVA) of Post-Attitude by Treatment, and Cognitive Ability

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>9030.397^a</td>
<td>24</td>
<td>376.267</td>
<td>7.746</td>
<td>0.000</td>
<td>0.331</td>
</tr>
<tr>
<td>Intercept</td>
<td>9461.404</td>
<td>1</td>
<td>9461.404</td>
<td>194.767</td>
<td>0.000</td>
<td>0.341</td>
</tr>
<tr>
<td>Pre-Attitude</td>
<td>1473.918</td>
<td>1</td>
<td>1473.918</td>
<td>30.341</td>
<td>0.000</td>
<td>0.075</td>
</tr>
<tr>
<td>Treatment</td>
<td>2710.739</td>
<td>2</td>
<td>1355.369</td>
<td>27.901</td>
<td>0.000*</td>
<td>0.129</td>
</tr>
<tr>
<td>Cognitive ability</td>
<td>310.782</td>
<td>2</td>
<td>155.391</td>
<td>3.199</td>
<td>0.042*</td>
<td>0.017</td>
</tr>
<tr>
<td>Treatment x Cognitive ability</td>
<td>358.620</td>
<td>4</td>
<td>89.655</td>
<td>1.846</td>
<td>0.119</td>
<td>0.019</td>
</tr>
<tr>
<td>Error</td>
<td>18265.384</td>
<td>376</td>
<td>48.578</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2174457.000</td>
<td>401</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>27295.781</td>
<td>400</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R Squared = .331 (Adjusted R Squared = .288) * denotes significant difference at 0.05
Table 7.4 shows that there is a significant main effect of treatment on pre-service teachers’ attitude to population education ($F_{(2,378)} = 27.901; p<0.05; \eta^2 = 0.129$). The effect size is 12.9%. Hence, hypothesis 1b was rejected. In order to determine the magnitude of the significant main effect across treatment groups, the estimated marginal means of the treatment groups was carried out, and the result is presented in Table 7.5.

Table 7.5: Estimated Marginal Means (EMM) of Post-Attitude by Treatment and Control Groups

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>TBLS</td>
<td>74.95</td>
<td>0.891</td>
<td>73.203 - 76.705</td>
</tr>
<tr>
<td>5ELS</td>
<td>79.81</td>
<td>1.340</td>
<td>77.171 - 82.442</td>
</tr>
<tr>
<td>CS</td>
<td>66.71</td>
<td>1.003</td>
<td>64.736 - 68.681</td>
</tr>
</tbody>
</table>

Table 7.5 reveals that pre-service teachers in the 5ELS Group 2 had the highest adjusted post-attitude mean score to population education (79.81), followed by the TBLS Group (74.95), while pre-service teachers in the CS Group had the least (66.71).

Table 7.6: Bonferroni Post-hoc Analysis of Post-Attitude by Treatment and Control Groups

<table>
<thead>
<tr>
<th>(I) Treatment</th>
<th>(J) Treatment</th>
<th>Mean Difference (I-J)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBLS</td>
<td>5ELS</td>
<td>-5.4117*</td>
<td>94232</td>
<td>0.000</td>
<td>-7.6777 - 3.1457</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>4.8550*</td>
<td>82473</td>
<td>0.000</td>
<td>2.8717 - 6.8382</td>
</tr>
<tr>
<td>5ELS</td>
<td>TBLS</td>
<td>5.4117*</td>
<td>94232</td>
<td>0.000</td>
<td>3.1457 - 7.6777</td>
</tr>
<tr>
<td></td>
<td>CS</td>
<td>10.2667*</td>
<td>97763</td>
<td>0.000</td>
<td>7.9158 - 12.6176</td>
</tr>
<tr>
<td>CS</td>
<td>TBLS</td>
<td>-4.8550*</td>
<td>82473</td>
<td>0.000</td>
<td>-6.8382 - 2.8717</td>
</tr>
<tr>
<td></td>
<td>5ELS</td>
<td>-10.2667*</td>
<td>97763</td>
<td>0.000</td>
<td>-12.6176 - 7.9158</td>
</tr>
</tbody>
</table>

* denotes significant difference at 0.05

Table 7.6 reveals that pre-service teachers exposed to 5ELS were significantly different from their counterparts taught using TBLS and those exposed to Conventional Strategy CS in their post-attitude to population education scores. This implies that the significant differences originated from the intervention of the 5ELS and TBLS.

Table 7.7: Estimated Marginal Means of Post-Attitude by Cognitive Ability

<table>
<thead>
<tr>
<th>Cognitive ability</th>
<th>Mean</th>
<th>Std. Error</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>72.56</td>
<td>.872</td>
<td>70.846 - 74.274</td>
</tr>
<tr>
<td>Medium</td>
<td>71.88</td>
<td>.756</td>
<td>70.391 - 73.363</td>
</tr>
<tr>
<td>High</td>
<td>77.08</td>
<td>1.579</td>
<td>73.970 - 80.181</td>
</tr>
</tbody>
</table>

Table 7.7 reveals that the high cognitive ability pre-service teachers had the highest adjusted post-attitude mean score to population education (77.08), followed by the medium cognitive ability level (71.88), and the low cognitive ability pre-service biology teachers (72.56).

**Ho3a: There is no significant interaction effect of treatment and cognitive ability on pre-service biology teachers’ achievement in population education**

Table 7.1 shows that there is a significant two-way interaction effect of treatment and cognitive ability on pre-service teachers’ achievement in population education ($F(4,376) = 2.440, p<.05; partial
\(\eta^2 = 0.025\). The effect size is 2.5\%. Thus, the null hypothesis 3a was rejected. This implies that treatment and cognitive ability had effect on pre-service biology teachers’ achievement in population education.

**Ho3b: There is no significant interaction effect of treatment and cognitive ability on pre-service biology teachers’ attitude to population education**

Table 7.4 shows that there is no significant two-way interaction effect of treatment and cognitive ability on pre-service teachers’ attitude to population education (F(4,376) = 1.846, p>0.05; partial \(\eta^2 = 0.019\)). Hence, the null hypothesis 3b was not rejected.

**DISCUSSION OF FINDINGS**

The finding from the study supports that of Ibrahim (2015) that pre-NCE Biology students exposed to 5E learning cycle in genetics concepts had higher mean performance scores than those in the control group exposed to lecture method of instruction. For team-based learning strategy, findings were in tandem with findings from studies undertaken by Koohestani and Nayereh-Baghcheghi (2016); Huggins and Stamatel (2015) who reported that students exposed to team-based learning strategy (TBLS) recorded improved academic performance than those exposed to the conventional strategy (CS). The finding alludes to that of Ibrahim (2015), Killins and Hult (2015) who in their respective studies used active learning strategies and reported that students exhibited positive attitude and improved classroom engagement which promoted interactivity between learners.

Finding was consistent with that of Ewumi and Olubela (2015) who reported no significant interaction effect of treatment and mental (cognitive) ability occurred on students’ achievement in and attitude to social studies. It also affirmed the outcome of the study undertaken by Babayemi & Akinsola (2014) that significant two-way interaction effect of treatment and mental (cognitive) ability on achievement in Basic science was not significant. However, results of this study did not support the findings of Awolere (2015) who reported that interaction effect of treatment and mental (cognitive) ability on students’ attitude to biology was significant. This variance could be due to the educational level of participants in the aforementioned study because studies have shown that students’ attitude to science declines as they advance in science education and school years (Potvin and Hasni, 2014; Sorge, 2007). While Awolere worked with secondary school biology students, this study focused on pre-service biology teachers in CoEs. It also means that as students advance in age and school years, their positive attitude to learning may wane unless efforts are geared toward sustaining it.

**CONCLUSION**

Teaching is a two-way communication process and any teacher who engages in this process should ensure that there is a connection between the speaker and the receiver which most often than not is lacking when the conventional strategy is adopted. In other words, the intuition of the teacher should spur him/her into ascertaining those factors that can ensure that this connection is sustained beyond the initial few minutes into the lesson. The two strategies have been found effective in enhancing pre-service Biology teachers’ achievement in and attitude to population education. Cognitive ability was a contributory factor to pre-service biology teachers’ achievement but not factors to their attitude to population education. Hence, these two strategies could be used to facilitate knowledge construction and application for improved achievement.

**RECOMMENDATION**

Employing active learning strategies such as TBL and 5EL by lecturers to teach population education would be a veritable means of developing and improving pre-service biology teachers’ ability to construct and reconstruct knowledge from learning experiences. This would impact positively on their ability to apply learned concepts to solving population issues in outside of the classroom.
Adopting these two strategies could be a formidable means of improving the academic achievement of pre-service biology teachers’ in population education which could in turn enhance their attitude to the subject.

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EFFECTIVENESS OF RECONCEPTUALISED NATURAL SCIENCES INTERVENTIONS IN MPUMALANGA

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ABSTRACT: The purpose of this paper is to explore the effectiveness of Natural Sciences interventions in one of the circuits in Mpumalanga. This paper uses pedagogical content knowledge and the instructional learning theoretical framework as a lens. Based on the outcome of baseline assessment of teaching practices in Natural Sciences in Grade 7, this paper adopted a qualitative research approach, using single case study design to explore the impact of interventions to assist teachers with content knowledge and teaching strategies that could be used for teaching Natural Sciences. Through observation and face-to-face interactions, this paper employed the purposive sampling method to select five teachers who participated in the interventions. The results of the paper suggest that science teachers in primary schools are still facing challenges such as a lack of resources, content knowledge barriers and neglectation. Furthermore, teachers expressed an opinion that following the interventions they would now be able to transform content knowledge into practice. The study recommends that the Department of Education should consider extending similar kind(s) of workshop presented to secondary school teachers to the primary school teachers. Earlier interventions would not end at elongating learners’ exposure, but would help to stimulate confidence, efficacy and mastery of sciences.

Keywords: Natural Sciences, pedagogical content knowledge, instructional theory, interventions

INTRODUCTION

In the 21st century teaching and learning of science requires dedication, passion and hard work. Although this demand is by no ways new, the advent of the so called fourth industrial revolution has attracted new interest in sciences as tributaries of technology. Over the years, South African Education system experienced a decline in the number of critical science professionals such as engineers, technologists, quantity surveyors, scientists, space and solar physicists, etcetera (South African Department of Labour, 2019). In trying to improve science related professionals, the Mpumalanga Department of Education (MDE) introduced science subject as compulsory to a sample of selected schools. This intervention resulted to about 101 schools in Mpumalanga having to intensify their focus on teaching mathematics and physical sciences as core subjects in the Further Education and Training Phase (FET) – Grade 10 to 12 (MDE, 2018). Despite efforts that were aimed at ensuring that learners were taught science in the upper grades of the selected schools, the number of learners who enrol in Mathematics Science and Technology (MST) schools has dropped drastically. This seems to be a general trend in the entire throughout the province, in most schools the number of learners who take science as a major subject in FET is on the decline. This can be attributed to a number of factors including the returning perception that science is difficult and challenging. The problem is further compounded by the scarcity of programmes that are intended to capacitate Natural Sciences (NS) teachers in schools in a sustainable way. Against this background this paper explores effectiveness of NS existing intervention in selected schools in the Bholabela district in northern areas of Mpumalanga.

This paper used observations as baseline assessment that resulted in teachers who teach NS in the lower grades (Grade 7 to 9) raising the need to be assisted with content knowledge, assessment and teaching strategies. As a result, this paper focusses on Grade 7 NS teachers who needed support in the form of interventions based on the following content: Planet Earth and Beyond, Matter and Materials, Energy and Change and Life and Living. Most of the teachers needed intervention in the content based on Planet Earth and Beyond. Few teachers requested interventions in Matter and Materials, Energy and Change and Life and Living although some of them requested interventions in the previously mentioned topics, it was discovered during the interventions that there are teachers who find some of the topics in Natural Sciences challenging. The two research questions of this paper were:
• What are the challenges faced by teachers when teaching Natural Sciences in Grade 7?
• How effective were the reconceptualised Natural Sciences interventions to Grade 7 teachers?

The following sections of this paper will review the literature, theoretical framework, results of this study, discussion of the results and the conclusion.

LITERATURE REVIEW

The paper explored the effectiveness of the reconceptualised NS interventions, which was the strategy that the researcher used in trying to reskill NS teachers of Grade 7 learners. Mpumalanga is facing a decline in the number of learners who enrol for pure science subjects in the FET phase. This could relate to a number of factors including lack of motivation on the part of learners to take science as their major subject in the FET phase. It can be anticipated that if this phenomenon is left uncorrected it has dire implications on retaining scientific knowledge in the long-term. For instance, Vedder-Weiss and Fortus (2018) indicated that the decline in motivation of adolescents to study science has resulted in a reduced number of science-related professions. Vedder-Weiss and Fortus (2018) further note that the decline in science-related professions is directly linked to teachers’ involvement in the classroom. In other words, corrective measures that would promote learner interest in sciences begins with the science teachers – their mastery of content knowledge, beliefs, and motivation. Where teachers do no longer believe in the usefulness, worth and value of sciences it cannot be expected that there will be improvements on the downward slope of learner selection of science as reliable pathway for their choice careers.

Ediger (2018) contends that science teachers need to provide science content in an interesting manner to arouse the interest of learners to become ready for science-related careers. Teachers who play an important role in teaching learners science subjects in the lower grades (primary school) might not always see it as their responsibility to motivate learners and teaching them with confidence they could pursue science at higher levels (secondary school). Researcher Akcay (2017) followed by Vedder-Weiss and Fortus (2018) are in agreement that learner support is needed, however this research identified differences in autonomous support between traditional and democratic schools. Traditional schools tended to follow archaic methods in which learners had partial involvement (if any) when identifying areas of support. This kind of learner exclusion often did not help to stimulate learner-interest. On the other hand, democratic school tended to rely on learners to make their own improvisation to generate their own learning. It is said that, teachers tended to cascade traditional science teaching to leaners, which result in the leaners not having opportunities to identify a problem or issue of personal interest (Akcay, 2017). Limitations of the latter approach is that learners cannot be expected to know about all their needs, teachers with expert knowledge need not desert their duty. In the end both the traditional and democratic approaches have strengths and weaknesses. The burden lies with teachers to gain expert knowledge about ways of stimulating learners’ motivation for science take-up.

According to Akcay (2017), science teachers should focus on the personal needs of learners; that is, science concepts and process skills that are useful in the daily living of learners. Akcay (2017) is of the view that if teachers embed societal issues in their teaching of science, which could include issues and problems at home, school, in the community and globally, they are more likely to see the relevance of science in their life and develop interest in science-related subjects. A good science teacher is observant if learners are engaged in learning and should be skilful and knowledgeable in selecting an appropriate method that applies to the evaluation process (Ediger, 2018). Thus, this paper explores the revitalised NS teacher’s intervention that aims at improving the content knowledge and teaching strategies of teachers that might indirectly motivate learners in the classroom. To assist science teachers, like the respondents in this study, Bantwini and Feza (2017) draw attention to the need of continuous professional development of science teachers that improves their
contextual needs, rather than a generalised version of it. In addition, teachers in the lower grades need to attend workshops frequently so that they are kept abreast with the ever-changing curriculum needs (Bantwini and Feza (2017). This paper explores the effectiveness of NS interventions where evidence has shown in other studies that classroom engagement is affected by classroom factors such as connective instruction, academic rigour and participatory teaching (Cooper, 2014).

THEORETICAL FRAMEWORK

The premise of this paper is pedagogical content knowledge (PCK) and instructional theories. On one hand, Shulman (1986) theorised that an expert science teacher knows the difficulties learners face and the misconceptions they develop. On the other hand, teachers should know how to utilise prior knowledge while presenting new ideas to help the learners develop a new and correct understanding which Schulman (1986) refers to as PCK. Bransford, Brown and Cocking (1999) noted that using PCK, teachers must firstly have an understanding of their subject (NS); secondly, they should know about the conceptual barriers that learners encounter in the subject. Lastly, the teachers should be acquainted with knowledge of effective strategies to work with learners. In this paper, PCK was chosen because it focuses on the content to be taught that teachers must possess to transform content knowledge into teaching. However, Bloom (1956) theorised instructional theory that is influenced by three basic theories in education, namely the theories of behaviourism, cognitivism and constructivism. Instructional theory explores how to help learners gain a better understanding of content (Bowden, 2008). The instructional theory also identifies strategies to be used in teaching and is adapted to the educational content and significantly on the learning style of the learners (Bowden, 2008). Therefore, this paper recognises the five universal methods of instruction: task-centredness, demonstration, application, activation and integration principles (Reigeluth, 1999). Reigeluth (1999) further contends that the main target audience of instructional theory is educational practitioners. Consequently, this is one of the reasons why this theory has been chosen for this study as the researcher explores the effectiveness of the reconceptualised NS interventions in Mpumalanga.

RESEARCH METHODOLOGY

This paper employed a qualitative research approach to find out the challenges and explore the effect of the reconceptualised NS intervention on teachers in the province. MacMillan and Schumacher (2010) revealed that qualitative research is used when little is known about a topic or phenomenon and when one wants to discover or explore further about the inquiry.

Research context

The qualitative study was undertaken in one of the four districts in Mpumalanga in the Agincourt circuit. Five schools were purposively sampled and five teachers were observed in baseline assessment while teaching NS in the classroom. The findings of the observation necessitated the researchers to conduct interventions for the Grade 7 NS teachers. The school selection criteria were as follows: they all reside in the same circuit and they are primary schools with classes starting from Grade 1 to Grade 7 and NS is one of the subjects taught in the school.

Research design

The paper used a single case study of Agincourt circuit where the teachers who participated in the observation were sampled. Creswell (2009) contends that a case study is a strategy of inquiry where the researcher explores a programme, event, activity and process of one or more individual. Similarly, cases are complex organisations that have parts and act or operate in their surroundings, as shown in this paper. According to Johnson and Christensen (2008), a case study is mostly used in education where the goal is to explore a programme and evaluate its effectiveness. This paper indeed explores the effectiveness of NS interventions.
Participants and data collection methods

The participants in this paper were sampled from all teachers who took part in the baseline assessment during observations. Nineteen teachers took part in the observations and the researcher conveniently selected five teachers from five schools in the circuit for interventions. All the participants taught NS in Grade 7. The age range of the participants was between 24 to 55 years, showing that the sample included inexperienced and experienced teachers. In the baseline assessment, data was collected, using observations and the NS interventions took the shape of face-to-face interactive discussions with each participant. According to Yin (2011) in qualitative interview a researcher can interview either a group of participants (focus group) or individuals. Creswell (2009) points out that an interactive interview is a useful tool when participants cannot be directly observed and they can provide more information during interviews. In the instance of this paper, the interviews were interactive in that reconceptualised intervention took place. The instruments used were observation and face-to-face interviews with open-ended questions posed to the NS teachers. Each teacher was exposed to presentations of NS content, using PowerPoint.

Data analysis and Ethical consideration

The procedure for data analysis in this paper was adopted from Creswell (2009) and involved the following steps: Step 1: Organising and preparing the data for analysis. This involves transcribing interviews, typing of field notes and arranging the data into different types depending on the sources of information provided. Step 2: Reading through all the data. Step 3: Conducting a detailed analysis of the coding process done at that stage. Data in this study are organised into segments. Step 4: Involves the coding process used to generate a description of the setting, people, and categories. Step 5: Emerging themes from the categories. This paper has the approval of the UNISA College of Education Research Ethics Committee. All ethical-related matters such as informed consent and assent, anonymity of participants, trustworthiness and so forth were considered during data collection and analysis.

RESULTS

Observations and face-to-face interviews revealed that most teachers both experienced and inexperienced are facing challenges of teaching overcrowded classrooms; a lack of teaching resources; a lack of in-service training and workshops on NS. In addition, teachers find themselves teaching NS out of specialisation – NS was not their major subject in tertiary education. While observing new and experienced teachers in the classroom, it emerged that some of them still have misconceptions about certain topics of NS. The teachers also revealed that they have challenges when transforming content knowledge into teaching and a lack of necessary teaching strategies that could be used in NS. As a result, the teachers requested interventions that were conducted by specialists in NS through a community engagement project. They requested to be capacitated the following content in Grade 7; Matter and Materials, Planet Earth and Beyond and Energy and Change. The results of this paper also suggest that the teachers benefitted from the interventions which were based on issues such as misconceptions, transformative teaching, difficult topics in the NS curriculum and strategies that can be used to teach practicals in the classroom.

DISCUSSION OF RESULTS

The discussion of results focusses on the effectiveness of the NS intervention for teachers with respect to two themes that emerged, namely content knowledge (transforming content knowledge into effective teaching and misconceptions) and teaching practices (strategies).

Content Knowledge

The teachers raised challenges in teaching Matter and Materials, Planet Earth and Beyond and Energy and Change; this was evident during the classroom observations while teaching NS. The teachers were then invited to individual discussions on content that is challenging to teach in the classroom. In Planet Earth and Beyond most teachers could not explain how
they could teach the topic ‘tides’ in the classroom; explaining it to learners is therefore a challenge. This scenario was observed in both inexperienced and experienced teachers. During the interventions, they were provided with NS topic-specific videos that could be used in the classroom to explain how tides are formed. Again, the challenge of most schools was the unavailability of overhead projectors and laptops that could be used to teach such topics in the classroom. The teachers were also provided with a practical explanation of the relationships of the sun to the earth, relationship of the moon to the earth and historical development of astronomy during the interventions. Some teachers were then afforded the opportunity to probe further into content that is problematic, leading to conducive dialogic conversations between the researcher and the teacher. The interventions also improved the new and experienced teachers’ understanding of the use of indigenous knowledge in NS topics. For example, in some South African cultures lunar eclipse represents a year of good harvest and prosperity meanwhile in other cultures it represents suffering and bloodshed. The teachers were capacitated to relate indigenous knowledge to science.

In Matter and Materials, inexperienced and experienced teachers were capacitated to use indigenous ways of separating mixtures, such as distillation. The teachers also had misconceptions in respect of Matter, Materials, for example that steam is hot air instead of being water vapour and that ice molecules are colder than water molecules instead of teaching that ice molecules have less kinetic energy than water molecules. Furthermore, some teachers taught the learners that condensation on the outside of the container is water that seeped through the walls of the container instead of saying that condensation of water vapour happens when the water vapour in air comes in contact with a cool surface. This confirms the instructional theory that identifies strategies to be used in teaching and is adapted to the educational content and significantly on the learning style of the learners (Bowden, 2008). In Energy and Change, teachers found the difference between potential and kinetic energy challenging and during the interventions, they were assisted in that practical examples were given to them that they can use in the classroom when teaching NS. Other studies have found that in-service education might assist new and veteran teachers with knowledge and skills that optimise learner achievement and progress (Ediger, 2018; Akcay, 2017; Brauer & Wilde 2018; Akpan, 2017). While other studies focused on transformative sustainable learning of science (Harmin, Barrett & Hoessler, 2017) and the implications of socio-scientific issues to improve critical thinking competences (Solbes, Torres & Traver 2018). What this paper finds different from the reviewed studies is that the analysis is based on the exact content that teachers felt in need to be assisted and the utilisation of specific ways of teaching NS, using indigenous knowledge, clarifying content barriers and using modernised teaching strategies in primary schools.

Effective Natural Sciences teaching practices

In this study, it was observed that most teachers still rely on traditional teaching methods for NS. For example, “chalk and talk” method, the lecture method, the teacher-centred approach and the teacher is in control and makes the decisions. According to www.rnitte.edu.pk (2019) these traditional methods encourage learners to master knowledge through drill and practice. The interventions encouraged both inexperienced and experienced teachers to employ modernised teaching strategies, such as visualisation, for example, pictures, diagrams and videos that would help teachers to review existing knowledge and help to introduce new knowledge (Farra & Rashid 2013). Other strategies that NS teachers should use are problem-based learning, small group discussions, social networks, such as WhatsApp, and collaborative teaching and learning. In support of these findings, Vedder-Weiss and Fortus (2018) contends that the learners should be allowed to make choices in their learning regarding aspects such as seating arrangement; content of assignment; groupings and methods of assessment. Akcay (2017) also draws attention to problem-based learning that it is important in science education where students develop skills, which allow them to become active, responsible people by responding to issues that affect their lives.
In support of small group instructions, Ediger (2018) believes that these instructions may engage learners in identified problems to solve from video presentation. For example, teaching the topic ‘tides’ in the NS classroom. The suggested strategies in teaching NS sought to present a teacher as a facilitator that guides learners where learners are the decision-makers and the master of knowledge by constructing it. The interventions also educated teachers in the importance of using PowerPoint presentations and worksheets for each topic on NS that is taught in the classroom. The findings of the paper anchor the sentiment of Bantwini and Feza (2017) who mention that there is a need for teacher support by school districts on how to teach the 21st century learner, including differentiated curriculum, instruction and assessment intended to deal with the needs of various learners and the mixed ability of learners in the in their classrooms. Most of the teachers were of the opinion that the interventions were necessary, they were revived in teaching NS, and they would implement all the recommendations made by the facilitators. To signify the importance of the interventions, most teachers encouraged the facilitators to avail themselves whenever they are needed.

CONCLUSION AND IMPLICATIONS

The findings of this study illustrate that new and experienced science teachers have massive responsibility not only to overcome the lack of teaching resources in the study area, but also to have them motivated to overcome content knowledge barriers and be in a position to transform content knowledge into practice in the classroom. Based on the two research questions of this study, it is important to note that the teachers have challenges in teaching NS and that the reconceptualised interventions on NS assisted them in finding a way forward to teach NS in future in a modernised society. This paper recommends that workshops be presented to all teachers, regardless of the grade they are teaching, so that they are kept abreast with the modernised curriculum and that they are able to transform content knowledge into teaching in the classroom. Further studies can be conducted on how effective the suggested teaching strategies to NS knowledge acquisition by learners.

REFERENCES


EFFECTS OF FELDER-SILVERMAN AND HONEY-MUMFORD LEARNING MODEL ON STUDENTS’ IN TECHNICAL COLLEGE

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ABSTRACT
In Nigeria, enhancing instructional delivery in Radio, Television and Electronics (RTVE) as a trade subject in technical colleges has become a great concern for technical teachers as it focuses on overcoming the challenges of assisting the learner to learn by enhancing their cognitive achievement and interest. The purpose of this study was to determine the effect of Felder-Silverman and Honey-Mumford learning models on students’ achievement and interest in RTVE. Two research questions and three hypotheses tested at .05 level of significance guided the study. The study adopted quasi-experimental design. The population for the study consisted of 60 National Technical Certificate level II (NTC II) RTVE students in Technical colleges in Nigeria Federal Capital Territory, Abuja. A population of 60 students consisting of 50 males and 10 females were assigned to two treatment groups. The instruments for data collection were Radio, Television and Electronics Achievement Test (RTVEAT) and Radio, Television and Electronics Interest Inventory (RTVEII). The RTVEAT and RTVEII; Felder-Silverman lesson plans and Honey-Mumford lesson plans were validation. The test-retest reliability was determined using Pearson Product Moment Correlation Coefficient and was found to be .91, while the internal consistency of the RTVEAT was determined by Kuder-Richardson 20 (KR20). The RTVEII was subjected to construct validation using principal component analysis. A total of 24 items were selected for the study in the interest inventory. The internal consistency estimate of the RTVEII was determined using Cronbach Alpha technique and was found to be .82. Mean was used to answer the research questions while, Analysis of Covariance (ANCOVA) was used to test the four hypotheses that guided the study at .05 level of probability. The study found out, among others, that Felder-Silverman learning model is more effective than Honey-Mumford learning model in improving students’ achievement and interest in RTVE. There was an effect of gender on students’ achievement and interest in favour of females. Gender had no significant effect on students’ achievement. The study found no significant effect of treatments and gender on students’ achievement and interest in RTVE. The study recommended among others that Felder-Silverman learning model should be adopted in the teaching/learning of RTVE in Technical Colleges. In addition, workshops, seminars and conferences should be organized by Federal and State Science and Technical Schools Board to enlighten and train RTVE teachers on the application of Felder-Silverman learning model for improving students’ achievement and interest in studying RTVE.

Keywords: Felder-Silverman, Honey-Mumford Learning Model   Achievement, Radio Television and Electronics Work, Technical College.

INTRODUCTION
Radio, Television and Electronics Work (RTVE) is one of the programs offered in technical colleges in Nigeria. It comprises the following modules; Basic Electricity, Electronics Devices and Circuit, Radio Communication, Radio and Audio Frequency amplifiers, Satellite Transmissions and Reception, Television, Electrical & Electronic Drawing, Colour Television, Radio & Electronics system (National Board for Technical Education,NBTE 2007). RTVE works is designed to equip students with hands-on experience in installing, maintaining and servicing of electronic devices and systems (NBTE, 2007). After three decades of implementing the National Policy on Education (NPE), Nigeria is yet to fully enjoy the benefit of the technical education component of the policy of which RTVE work is one. However, as a result of the ever increasing change and development in Technology, RTVE work has become complex. Television, radio and other electronic devices no longer have large component, they now come in Nano sizes which requires high skills to work on (Raymond, 2013).
This technological development in workplace and industry has necessitated the need to equip students of RTVE work with basic thinking skills which will make them adapt to the present and envisaged future change in this workplace and industry (Ogbuanya & Owodunni, 2015). The National Board for Technical Education (NBTE, 2007) maintained that RTVE craftsmen are expected to: understand basic principles of radio transmission and reception, basic skill on satellite transmission and reception, troubleshoot and repair faulty equipment, understand principles of amplifier and its operation, understand television, camera and closed circuit, electronic component and symbols and electrical component.

Therefore, for students to acquire the adequate skills needed, several factors ranging from the student, teacher, families and school need to be in place to prepare them in all areas of life challenges. However, several researchers and educators have found that one major factor affecting student achievement is learning style (Zhang, 2005; Bargu, 2013). Owodunni, (2010) in a study found that the poor achievement of student in RTVE work was as a result of the learning styles of the students not being considered in the process of teaching and learning of the course. Graf, Liu & Kinshuk (2010) also pointed that students’ achievement could be improved if learning styles could be taken into consideration when developing any learning plan. Mutua (2015) also noted that there is a strong intuitive appeal in the idea that instructors, course designers and educational psychologists should pay closer attention to student learning styles by diagnosing them, by encouraging learners to reflect on them and by designing teaching and learning process around the learner’ learning style. When this is done it will to help reach more students because of better match between teacher and learner styles.

The research on learning styles has been active since four decades ago (Cassidy, 2004). There exist various definitions for learning styles. As refer by Campbell et al. (2003), learning styles is defined as a certain specified pattern of behaviour according to which the individual approaches learning experience. While Felder and Spurlin (2005) defined learning styles as the different ways students take in and process information. Another popular definition for learning styles refers to individuals’ characteristics and preferred ways of gathering, organizing and thinking about information (Fleming, 2005). As noted by Kolb and Kolb (2005), learning styles are not fixed personality traits but rather one’s adaptive orientation to learning. Felder and Spurlin (2005) shared similar view with Kolb by which they stressed that “learning style profiles suggest behavioural tendencies rather than being infallible predictors of behaviour”. Many of the researchers did agree that individuals may tend to have a preference for one or two learning styles over others and the preferences can be affected by a student’s educational experience (Felder & Spurlin, 2005). Throughout the learning process and based on different educational experience, the students may discover better way of learning and develop certain learning preferences, which will help in enhancing the academic achievement and interest on what is being taught.

Moreover, the problem does not only lie in just the teacher identifying the student learning styles in teaching and learning of any course including RTVE but proper matching. Graf and Kinshuk (2010) observed that a good match between students’ learning style and teachers’ teaching style has been demonstrated to have positive effect on students’ achievement. Teaching styles also vary as much as learning style varies. Teachers have different strength and preference with regards to how they develop an individual’s learning and learning styles (Suntonrapot, 2014). Some teachers gives lectures, some demonstrates or discuss, while some focus on rules and others on example, some emphasize memory and other understanding. In view of this, Mehigan (2013) established that some students seem to learn better when information is presented through word (verbal learners), whereas others seems to learn better when it is presented in the form of picture (visual learners). This clearly shows in a class where only one learning style is employed, there is a strong possibility that a number of students will find the learning environment less optimal and this could affect their academic achievement (Ibe, 2015). Furthermore, there are several learning styles but the study is considering the effect of Felder- Silverman learning style model and Honey-Mumford
learning model on student achievement and interest in RTVE work. The two models seem appropriate for the study because of its ability to develop student achievement and also because RTVE work is considered to be an engineering course (NBTE, 2007).

Student achievement is seen as how successful the learner can master the materials of the learning object (Raymond, 2013). It is the extent to which a student, teacher or institution has achieved their educational goals. Student achievement is commonly measured by examinations or continuous assessment. Furthermore, the more the interest of the learner in any subject the better the student’s achievement. Schraw et al. (2001) state that interest is the attraction which forces or compels a learner to respond to a particular stimulus. Interest increases learning therefore promoting interest in the classroom increases student intrinsic motivation to learn. An engaged learning environment promotes student interest in learning, this means that when learners are involve in the learning process with rapid interest, learning is facilitated and achievement can be enhanced. Student interest in any learning activity can therefore be sustained by the active involvement of the learner in all aspect of the learning process. Obodo (2004) maintained that interest control the motivation to learn, thus it has a direct relationship with student achievement in any school subject. Therefore the study seeks to determine the effect of Felder-Silverman and Honey-Mumford learning model on student achievement and interest in RTVE.

STATEMENT OF THE PROBLEM

The rapid rate of technology development in RTVE work and the increasing demands on cognitive skills in RTVE work calls for a change in the instructional delivery system used in training RTVE craftsmen in Technical Colleges. It is observed that most of the RTVE craftsmen graduating from Technical Colleges often find it difficult to adapt and apply their knowledge and skills to trace and rectify RTVE problems under varying technological situations. The learning method applied in training RTVE students in Technical Colleges do not give student enough opportunities to be fully involved in the learning process; this is because the teacher is seen as the fountain of knowledge, making the whole process a teacher-centred. This leads to difficulties in learning, disinterest and low academic achievement by the students. Not all students learn the same way; it become imperative that teachers realize the learning style differences and teach in a manner in which all learning style are incorporated to ensure that large number of student learn equally and effectively. However, several researches in the past has pointed to the high weakness in the conventional method in teaching and learning of engineering trade such a RTVE work in Technical Colleges. In this 21st century where technology advancement changes by the day, a more effect teaching and learning approach is required to match the present day challenge and also the future. More so, research has shown that teaching process rooted in Felder – Silverman learning model and Honey-Mumford learning model are capable of enhancing the learners’ abilities and developing problem solving and higher order of thinking skills in the learner as well as improving interest in chemical engineering. Therefore a more reliable instructional delivery system is required to enhance RTVE craftsmen in Technical Colleges.

Hence the need for the study is to determine the effects of Felder – Silverman and Honey-Mumford learning model on students’ achievement as well as interest in studying RTVE in Technical Colleges in FCT?

AIM AND OBJECTIVE OF THE STUDY

The study determined the effect of:

1. Felder-Silverman and Honey-Mumford learning models on student academic achievement in RTVE
2. Felder - Silverman and Honey-Mumford learning models on student interest in RTVE

RESEARCH QUESTIONS

The following research questions are structured to guide the study
1. What is the effect of Felder–Silverman and Honey-Mumford learning models on students’ academic achievement in RTVE?
2. What is the effect of Felder-Silverman and Honey–Mumford learning models on students’ interest in RTVE?

HYPOTHESES
The following null hypotheses guided the study

HO₁: There is no significant difference between the effect of Felder-Silverman learning model (FSLM) and Honey-Mumford learning model (HMLM) on students’ academic achievement in RTVE.

HO₂: There is no significant difference between the effect of Felder–Silverman learning model and Honey–Mumford learning models on students’ interest in RTVE.

METHODOLOGY
The design of the study was quasi-experimental research design. The research made use of pre-test, post-test non-equivalent control group design. The researcher randomly assigned intact classes to treatment and control groups. This was necessary in order not to disrupt the normal classes of the students and the school time-table. The population of this study comprises 60 (50 male and 10 female) year II students of Radio, Television and Electronic works in the technical colleges that offered the course in FCT, Abuja. The entire population was used for the study. The instruments used for data collection were Radio, Television and Electronic Achievement Test (RTVEAT) and Radio, Television and Electronic Interest Inventory (RTVEII). Also Felder-Silverman Learning Inventory and Honey-Mumford Learning style inventory was used to identify the student learning style. To ensure content validity of the RTVEAT, a table of specification was built for the test. The Felder-Silverman and Honey-Mumford lesson plans, RTVEAT, RTVEII and the training manual were subjected to face validation by three experts. The RTVEAT was trial-tested to determine its psychometric indices and reliability coefficient. The trial test for determining the coefficient of stability of the RTVEAT was carried out using test re-test reliability technique. Pearson Product Moment Correlation coefficient of the RTVEAT was found to be 0.91 while the reliability of the RTVE Interest Inventory (RTVEII) was determined by computing the Cronbach Alpha internal consistency coefficient of the pilot test scores of the 24 item RTVEII which was found to be 0.82. The RTVEAT and RTVEII items were subjected to face and content validation by Electronic works Lecturers experts at University of Technology Minna, Nigeria. It entailed checking the RTVEAT and RTVII items against the topic and content of the lesson plan.

The researcher prepared two (2) sets of lesson plans for the teaching of the module set out for the study. These lesson plans were prepared from the units in the test blue print. Each set contains eight (8) lesson plans that lasted for a period of eight weeks and 90minutes duration. One set of the lesson plan was written based on Felder–Silverman Learning Model, the subject teacher in the experimental group applied this lesson plan at different stages of instructional process, while the second set was prepared based on Honey-Mumford learning model in teaching the RTVE work students.

The research questions were analysed using the mean and Standard deviation while analysis of covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significant. Since students in their intact classes (non-randomised groups) participate in the experiment, ANCOVA was considered appropriate for analysing the difference between the effects of the treatments on the dependent variable. The results that were obtained was analysed via version 20 SPSS. The F value and probability level (0.05) was used to make decision, hence any F value that is less than the probability value (p 0.05) was rejected and any F value that is greater than probability level (p 0.05) was accepted.

RESULTS

Research Question One: What is the effect of Felder–Silverman and Honey-Mumford learning models on students’ academic achievement in RTVE?
Table 1: Pre-test and Post-test mean Scores of Treatment Groups Taught with Honey-Mumford and Felder-Silverman Learning Model in Radio, Television and Electronic Academic Achievement Test.

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Scores</th>
<th>Posttest Scores</th>
<th>Mean Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMLM</td>
<td>25</td>
<td>5.56</td>
<td>25.88</td>
<td>20.22</td>
</tr>
<tr>
<td>FSLM</td>
<td>35</td>
<td>5.74</td>
<td>26.86</td>
<td>21.12</td>
</tr>
</tbody>
</table>

N= Number of students, \( \bar{x} \)= Mean, HMLM=Honey–Mumford Learning Model, FSLM=Felder-Silverman Learning Model.

The result presented in Table 1 reveals that treatment group taught RTVE with HMLM had a mean score of 5.56 in the pre-test and a mean score of 25.88 in the post-test making a pre-test post-test Mean gain of 20.32. The treatment group taught RTVE with FSLM had a mean score of 5.74 in the pre-test and a post-test mean of 26.86, with a mean gain of 21.12. The analysis of the result shows that achievement scores of FSLM is higher than achievement score of student in HMLM; therefore FSLM is more effective in improving students’ Academic achievement in RTVE.

**Research Question Two:** What is the effect of Felder-Silverman and Honey–Mumford learning models on students’ interest in RTVE?

Table 2: Pre-test and Post-test Interest Scores of students taught with Honey - Mumford Learning Model and Felder- Silverman Learning Model

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Scores</th>
<th>Posttest Scores</th>
<th>Mean Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMLM</td>
<td>25</td>
<td>1.43</td>
<td>2.99</td>
<td>1.46</td>
</tr>
<tr>
<td>FSLM</td>
<td>35</td>
<td>1.49</td>
<td>3.17</td>
<td>1.68</td>
</tr>
</tbody>
</table>

The result presented in Table 2 shows that interest inventory of RTVE student with HMLM had a mean score of 1.43 in the pre-test and a mean score of 2.99 in the post-test making a pre-test post-test mean gain of 1.46. The treatment group taught RTVE with FSLM had a mean score of 1.49 in the pre-test and a post-test mean of 3.17, with a mean gain of 1.68. The analysis of the result shows that both HMLM and FSLM are effective in improving students’ interest in RTVE, but FSLM is more effective in improving students’ interest in RTVE than the HMLM.

**Hypotheses Testing**

**H0:** There is no significant differences between the academic achievements mean score of student with Felder–Silverman and Honey–Mumford learning models.

Table 3: Summary of ANCOVA of Academic achievement Score of Student Taught RTVE with Felder-Silverman Learning Model and Honey-Mumford Learning Model

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>Df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>163.796*</td>
<td>4</td>
<td>40.949</td>
<td>1.218</td>
<td>.314</td>
</tr>
<tr>
<td>Intercept</td>
<td>4025.143</td>
<td>1</td>
<td>4025.143</td>
<td>119.728</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td>119.909</td>
<td>1</td>
<td>119.909</td>
<td>3.567</td>
<td>.000</td>
</tr>
<tr>
<td>Treatment</td>
<td>8.266</td>
<td>1</td>
<td>8.266</td>
<td>.246</td>
<td>.000</td>
</tr>
<tr>
<td>Treatment*Gender</td>
<td>1.741</td>
<td>1</td>
<td>1.741</td>
<td>.052</td>
<td>.821</td>
</tr>
<tr>
<td>Error</td>
<td>1849.054</td>
<td>55</td>
<td>33.619</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>43989.000</td>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2012.850</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Significant at sig of F< .05, Df= Degree of freedom
The result in Table 3 shows the F-calculated values for effects of treatment on Technical college students’ Academic achievement when taught RTVE using Felder- Silverman and Honey - Mumford learning models. The F-calculated value for treatment groups is 0.246 with a significance criterion (sig) at 0.000 which is less than 0.05. This means that the null hypothesis was rejected. Therefore, there is significant difference between the achievements mean scores of student with Felder–Silverman Honey–Mumford learning models.

\( H_0 \): There is no significant difference between the effect of Felder–Silverman learning model and Honey–Mumford learning models on students’ interest in RTVE

<table>
<thead>
<tr>
<th>Table 4: Summary of ANCOVA of Interest Score of Student Taught RTVE with Felder-Silverman Learning Model and Honey-Mumford Learning Model</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Source</strong></td>
</tr>
<tr>
<td>Corrected Model</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>preQues</td>
</tr>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>RTVI</td>
</tr>
<tr>
<td>Geder * group</td>
</tr>
<tr>
<td>Error</td>
</tr>
<tr>
<td>Total</td>
</tr>
<tr>
<td>Corrected Total</td>
</tr>
</tbody>
</table>

*Significant at sig of F<.05, Df= Degree of freedom

The result in Table 4 shows the F-calculated values for effects of treatment on students’ interest when taught RTVE using Felder-Silverman and Honey-Mumford learning models. The F-calculated value for treatment groups is 4.810 with a significance criterion (sig) at 0.033 which is less than 0.05. This means that the null-hypothesis was rejected. Therefore, there is a significant difference between the effect of Felder–Silverman learning model and Honey–Mumford learning models on students’ interest when taught RTVE using Felder–Silverman learning model and Honey–Mumford learning models.

DISCUSSION

Finding on research question one revealed that Felder-Silverman learning model and Honey-Mumford learning model are effective in improving students’ Academic achievement in RTVE, but the effect of Felder - Silverman learning model in improving students’ academic achievement in RTVE is higher than Honey–Mumford learning model. Analysis of covariance was used to test the first hypothesis shows the F-calculated values for effects of treatment on Technical college students’ Academic achievement when taught RTVE using Felder-Silverman and Honey-Mumford learning models. The F-calculated value for treatment groups is 0.246 with a significance criterion (sig) at 0.422 which is greater than 0.05. The result shows that the difference between the effect of Felder - Silverman learning model and Honey- Mumford learning model in RTVE academic achievement was statistically significant.

This means that Felder -Silverman learning model is more effective than Honey- Mumford learning model in improving students’ academic achievement in RTVE. These findings are consistent with the findings of Chen and Manjit (2015), Akinbobola, (2015) and Sharon (2014) who, in their report found that the Felder– Silverman based instructions had significant effect upon the students’ academic achievement than other instructional models.

The findings of this study also support some literature evidence such as Kolb and Kolb (2005) who stated that when learners are exposed to new ideas that are presented through different intelligences, they will have a better chance to learn, remember the information and apply their learning experiences to other situations which can lead to higher achievement. Therefore, the result of this study with regard to students’ academic achievement is attributed to the treatment given to students in Felder -Silverman learning model group and Honey-
Mumford learning model group. The findings could be explained by the fact that teacher’s adoption of various instructional techniques (such as active learning, Global learning, visual learning, Verbal learning and reflective learning) in the Felder - Silverman classroom appealed to the students’ different learning style and engaged the students in the learning process which increased their motivation to learn and strengthened their memory. The results could as well be explained thus: giving students opportunity to participate actively in the classroom through free interaction with the teacher and their peers and allowing them to learn in groups and assess their performance themselves which in turn engaged the students in the learning process. This, in turn, improved their learning and thinking abilities which led to deeper understanding of difficult technology concepts and principles associated with RTVE. It implies that students in Felder - Silverman learning model group remembered and applied more of their learning in RTVE than the other group of students that were taught through Honey - Mumford learning model. Also there was more opportunity for students’ participation in the class activities base on the different learning styles covered by Felder-Silverman learning model as to that covered in Honey-Mumford. This discovery is in agreement with the opinion of Akinbobola (2015) that reported that Felder-Silverman learning model has the ability to involve learners in more active participation based on tendencies, acknowledging the fact that learners with a high performance for certain behaviour can also act differently on occasions and also the Felder-Silverman learning model describes the learning style of a learner in more detailed form which provides the teacher better understanding of the students more than the Honey- Mumford learning model that streamline students learning into just four style.

Additionally, the findings for research question two revealed that Felder - Silverman learning model and Honey - Mumford learning model are effective in improving students’ interest in RTVE, but the effect of Felder - Silverman learning model in improving students’ interest in RTVE is higher than Honey - Mumford learning model. Analysis of covariance was employed to test hypothesis four at the calculated F-value (4.810) significance of F (0.033) and confidence level of .05. This means that the null-hypothesis was rejected. Therefore, there is a significant difference between the effect of Felder–Silverman learning model and Honey–Mumford learning models on students' interest in RTVE. This discovery confirmed the findings of Akinbobola (2015) who reported that using Felder-Silverman learning model in the classroom makes lessons more interesting, which causes students to pay more attention to what is taught and then learned. This is as a result of the various activities carried out in the class in other to the need of the various learning styles in the class. Felder and Silverman (1999) also explained that, identifying the student learning style and articulating the lesson around the student’ style in the classroom will allow teachers to specifically target all the students. This will activate students’ interest and get them involved in the learning process and also give them more exposure to the lesson content, and more opportunities to connect with the material. The results could, therefore, can be further explained by the fact that teaching in accordance to students’ strengths (learning styles) engages the students in the learning process. This, consequently, increased their self-esteem and enthusiasm in studying RTVE.

Similarly, the result that Honey - Mumford learning model is effective in stimulating students' interest in studying RTVE supports Ibe (2015) writings which stated that experiential learning is an excellent way to provide students with ownership over their learning progress. This also means the higher this ownership, the higher the intrinsic motivation to learn. The result could be explained by the fact that the experiential learning cycle in Honey - Mumford learning model engaged students in this group in the learning process through experiencing (activist e.g. in solving RTVE faults), reviewing (reflector e.g. in steps/procedures involved in tracing and diagnosing of electrical faults), concluding (theorist e.g. of signs and symptoms of RTVE faults) and planning (pragmatist e.g. of electrical fault finding techniques). This seems to have positive effects on students’ interest in studying RTVE.
CONCLUSION

The present rapid change in electrical and electronics technology development which led to the complexity and difficulty in troubleshooting and repair of radio, television and electronic gadget experienced by technical college students has given rise to the demand for better teaching and learning style that will help meet the present day demand. Consequent upon this, the study determined the effect of Felder–Silverman and Honey – Mumford learning models on students’ achievement and interest in RTVE in Technical Colleges and found out that Felder-Silverman learning model is more effective in improving student’s achievement in RTVE than Honey-Mumford learning model. This then therefore mean that Felder-Silverman learning model is a dependable option for teaching and learning in the present era of rapid technological development as it promote active and efficient learning which can lead to the acquisition of necessary skills for employment.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. Workshops, seminars and conferences should be organized by both Federal and State Science and Technical Schools Board to enlighten and train RTVE teachers on the application of Felder-Silverman learning model for improving students’ achievement and interest in studying RTVE.
2. National Board for Technical Education (NBTE) should consider the review of curriculum for RTVE with a view to incorporating activities that reflect students’ learning Style to enable students learn more effectively.
3. RTVE teachers in technical colleges should adopt Felder-Silverman learning model in their classroom teaching. This will help the teachers equip RTVE craftsmen with the knowledge and skills needed to easily cope and perform more effectively in the Electrical and Electronic world of work.
4. Both Federal and State Science and Technical Schools Board should equip workshops in technical colleges with relevant modern equipment, tools and machines. This will help improve student’s acquisition and mastery of skills.

REFERENCES


ABSTRACT – Low success rates in first year university modules can lead to lack of progression and reduced student success. One principal reason is that failing some subjects has a greater impact on progression than others. In this study a first year module that was marked as a priority module in the undergraduate BEd course was revised and reconceptualised using pedagogically sound design principles derived from a design-based research approach. The research explains how an institutional intervention plan was replaced by sound module design and innovative teaching in a blended mode to address poor student success in previous years. The design-based research approach led to a number of draft design principles which were tested and refined throughout the presentation of the module in 2019. Besides the design principles, a number of other strategies and ideas led to an extremely positive outcome and greater student success in a module focusing on 21st century teacher skills.

Keywords: Preservice Teacher, 21st Century Skills, Learning Technologies

INTRODUCTION: THE EVOLUTION OF AN UNDERGRADUATE MODULE – FROM TEACHER TO 21ST CENTURY TEACHER

Student success has been a priority at many universities worldwide for some time now. The institution where this study was done has taken massive steps to improve student success and is seen as a leading national example of institutional approaches to fostering student success. This has resulted in great gains in terms of student success with module credit success rates moving up by more than 10% over the past 8 years to be above 85% in 2016. Student feedback has also indicated that students are continuously reporting positive perceptions of their experience of their education and the support they receive. Other data have proved to be more worrying. This includes the indications that only approximately 37% of students from the new 2012 cohort completed their qualifications in minimum time (M) and approximately 55% of the same group in minimum time plus one year (M+1). These figures clearly illustrate that the high module credit success rate does not translate into high minimum time completion rates. There are many reasons for the low completion rate. One principal reason is that failing some subjects has a greater impact on progression than others. Major subjects and prerequisites that are failed often lead to an automatic extension of the completion time for a student. In addition to this, many students are not able to take a full course load (or think they can’t) because of previous failures which means they are not able to complete their studies as quickly as possible. This aspect of the problem is clearly illustrated by the fact that the actual total course load taken by undergraduate students at the institution amounted to only 82% of the possible course load during 2016. Many students are therefore extending their time to completion which has a number of detrimental effects on them, the institution and on students wishing to enter the system.

An introductory module presented in the first semester of the first year of the new BEd undergraduate programme at our university has had a very interesting beginning. The course design has evolved over the past two years which has had an influence on both the teaching of the content, as well as the way in which the students experience the offering. In 2018, for example, the module (simply named Teaching Studies 1A) was presented by a team of six lecturers who divided up the teaching load with meticulous detail. Lecturer teaching load per week was meticulously calculated according to individual workloads, and lecturers were allocated segments of the proposed content to present over the 14-week period of the module. The seemingly random allocation of lecturers came from a single department within the Faculty of Education, namely the Department of Science and Technology Education but there was still no real sense of unity. Lecturer expertise included Science Education (the coordinator), Mathematics Education (two colleagues), Learning Technologies, as well as Technology Education (two colleagues). These lecturers did not, however, teach their own
subject specialities, but rather focused on the more generic roles that a young teacher should play.

Focusing on the roles of the teacher, the module claimed to offer an introduction to the teaching profession and what it would take to be a successful teacher in the modern age. The ultimate aim of the module was, of course, professional development of the pre-service teacher. The broad topics covered in this module roughly followed the chapters in the prescribed e-textbook (Gravett, De Beer & Du Plessis, 2014) and included the following roles of the teacher: The teacher as caring professional, the teacher as reflective practitioner, the teacher as mediator of learning, the teacher as classroom manager, the teacher as curriculum interpreter, designer and implementer, the teacher as educational theorist, the teacher as assessor, and the teacher as user of media. According to Sahlberg (2004), globalisation is reshaping the role, purpose, process and ultimately the outcomes of teaching, learning and assessment. As a result the demand for a highly qualified and competent teaching force has become central to education reform. One of the by-products of globalization is the growing expectation of teachers to prepare, empower and equip students to achieve and reach their full potential which would allow them to become active and valuable members of a 21st century society who “have the opportunity to shape the fourth industrial revolution” (Schwab, 2017). The ever changing nature and variety of these expectations mean that teachers, more than ever before, must be able and equipped to make decisions based on a logical, robust and updated foundation of knowledge.

In 2018, the module coordinator took on the teaching load over four weeks, along with one other colleague taking on the same load. Another colleague taught for three weeks, and the remaining three colleagues each did a cameo appearance of one week each. Each weekly session included a double period lasting roughly one and a half hours. The 540 students were also divided up between the lecturers for assessment purposes (excluding the coordinator) with the highest number of students to assess being 216, with the second most being 162, and the other three colleagues having to mark 54 each. This only applied to the final written assessment as the rest of the formative assessment tasks were all in an online quiz format which was marked by the electronic learning platform (BlackBoard).

The online component of the module in 2018 not only included the electronic quizzes but also made use of the other basic functionalities of the BlackBoard platform like announcements and discussions. Details of the face-to-face contact sessions were also posted online along with some supporting materials, including links to relevant resources and web sites.

IDENTIFYING THE PROBLEM

The institutional aim is to set minimum requirements for student success activities as well as provide optional additional activities; to strengthen data analytics and data-informed decision-making with regard to student success by identifying problem areas and blockages; to track student performance and ensure that students complete qualifications as efficiently and timeously as possible. The approach involves both faculties and professional support services and includes a variety of tailor-made interventions to promote student success.

As early as February 2018, a Faculty Intervention Plan was put into place to address feedback from students and tutors at that point. The feedback indicated that many students do not have personal devices. For this reason, amongst others, students experienced difficulty downloading the e-textbook while others found it difficult to adapt to the new academic environment within the first few months. The online environment was also seen as huge adaptation for some students. The need for BlackBoard training was identified as well as the need for more tutors and more appropriate venues for tutorials (the dedicated tutor room which is used by all education students at various levels was deemed to be inappropriate for this function). To compound student problems, the examination paper had been scheduled on the last Friday of the examination period during the afternoon session.
In September 2018, this module was identified as being part of the 20% of modules where the most first time enrolments were lost, due to a variety of reasons. This 20% of priority modules is selected by incorporating the number of students registered in a module; the module pass rate and the module’s first time enrolment weighting (FTE) into a formula which then produces the Priority Module Index (PMI) list. The data from the PMI was previously used to inform the Intensive Revision Programme at the university, but with this more strongly data informed approach, the value and use of the PMI has been deepened and expanded. The PMI is now drawn in the semester preceding the re-offering of the modules (for example, the first semester 2018 PMI was used to guide the first semester 2019 interventions). Out of 494 students in the 2018 cohort who completed the module, 64 failed. A number of issues that have already been mentioned in the introduction are problematic in themselves and have played a role in this phenomenon. Students experienced a number of issues, including the large number of lecturers who engaged with them during contact sessions, a seemingly disjointed curriculum, and lecturers who played a role but had no real ownership of the sections they taught. Having several lecturers (eight in 2017 and six in 2018) to facilitate the content was not the ideal situation.

As part of the university intervention programme, a revision intervention was planned for the June holiday before the supplementary examinations to assist students who underperformed in the module. Resource materials were made available online via BlackBoard for additional revision and for students choosing not to attend these sessions. Unfortunately, while the plan was rather detailed and specific, very little happened by way of implementation. One workshop was arranged in the end. For this reason, a plan had to be made for the 2019 intake to prevent the mistakes of the past. We also had to ensure that creativity and technology were infused into an authentic 21st century educational experience (Herikson, Mishra & Fisser, 2016).

After a few meetings with the coordinator of the academic intervention programme it was decided that we could go ahead with our own intervention based on the strategy described in the preceding text. We felt that it was difficult to see a place for an “outside” intervention in our module without having the opportunity to first try our research-driven approach. Fortunately, our request was well-received and we were able to implement the changes based on sound pedagogical design. This plan involved a complete redesign of the module to incorporate elements of best practice in both the online and face-to-face spaces. In order to do this it would be necessary to derive a number of design principles that would ensure student success in this blended space and to implement the draft design in 2019.

METHODOLOGY: DERIVING AND IMPLEMENTING APPROPRIATE DESIGN PRINCIPLES IN A BLENDED MODE MODULE FOR FIRST YEAR 21ST CENTURY TEACHING STUDENTS

Design-Based Research, originally conceptualized under the guise of Design Experiments (Brown, 1992; Collins, 1992; Reeves, 2000), Development Research (Reeves, 2000; Van Den Akker, 1999) or Design Research (Bannan-Ritland, 2003; The Design-Based Research Collective, 2003; Kelly 2003; O'Donnell 2004;) was selected to address the goals of this project. Educational Design Research, According to Reeves, Mckenney And Herrington (2011) “provides a potentially viable alternative to the kind of educational research that is commonly conducted in the field of learning technology,” In my quest to remain relevant through this research, i chose to solve a practical problem in my own teaching (the issue of student success in a blended mode module) while simultaneously “constructing a body of design principles that can guide future development efforts” (Reeves, Mckenney & Herrington, 2011). Pedagogic design should be grounded in theory and theory driven (Barab & Squire, 2004). To achieve this aim, i set out to explore the pedagogic complexities of incorporating learning technologies and twenty-first century skills into an undergraduate pre-service teacher module that focuses on teaching in the 21st century.
Figure 1: Design-Based Research According to Herrington, Mckenny, Reeves and Oliver (2007)

As suggested in the first phase of the design logic presented in Figure 1, this study began with an in-depth investigation involving discussions with the key role players in the study (McKenney & Reeves, 2018). These role players included the previous teaching staff, the students, and the tutors. Also included in the mix was the coordinator of the university intervention program from the Academic Development Centre (ADC) who made the profound statement that “I also want to draw your attention to the fact that of all the modules in Education, this one is the best opportunity we have to make a noticeable impact on student success.” Some of the initial draft design principles for the 2019 blended module came from early interactions with key individuals in the ADC and from their policies and guidelines. Design principles from these sources that were most relevant to this module included:

- Gain the support of top management at Institutional, Faculty and Divisional level
- Put into place appropriate and effective Institutional and Faculty structures to support the implementation and to evaluate student success efforts in these domains
- Elicit participation and involvement by all relevant staff to ensure maximum efficacy
- Focus on student success related data analytics and data informed decision-making processes at the institution
- Provide effective and expanded online support (the online component was redesigned to incorporate elements of good online pedagogical design)
- Optimise resources to support student success at all levels
- Initiate inter-divisional partnerships to enhance student success (in this regard we partnered with the Academic Development Centre as well as with the Centre for Academic Technologies)
- Use student success efforts to influence what happens in the classroom (this is a key space for improving student success and in implementing effective interventions)

Through further surveys and interventions run by the Academic Development Centre (ADC) I was also able to interpret data which portrayed the voices of both students and tutors. From this data, and supported by focused reading in a variety of fields including pedagogical design, the fourth industrial revolution, 21st century teaching, and learning technologies (during the second phase in Figure 1), I was able to distil further draft design principles to guide the design of the new iteration of the module in 2019. The focused reading to discover further design principles for blended teaching approaches added to personal entrenched principles that have developed over my many years of teaching. Most of the design principles were, in fact, derived from my personal experience as facilitator of fully online modules at the university (and that of my fellow online lecturers). Most of the draft design principles used in the re-design of the new module for 2019 were common sense principles that should work in the design of any generic undergraduate module. Logically, the first iteration of the 2019 teaching was based on some theoretically grounded principles, some principles derived from the literature, principles derived from experiences of fellow lecturers, and some personal preferences and intuition based on recent experiences of teaching fully online modules.

Some of these early draft design principles include:
• Match the assessment strategy during the semester with the final summative assessment - Previously the module made use of a continuous assessment model, which relied on online quiz format using mostly multiple choice type questions. The exam was, by contrast, a written exam consisting of short and long questions. Learning Development will assist the module-coordinator with informing students of how to prepare for an exam.
• Increase student attendance of the face-to-face sessions by making them a meaningful part of the learning process
• Conceptualise face-to-face sessions based on sound pedagogical principles and supported by well-designed online units in BlackBoard.
• Ensure that the online components are engaging and challenging to ensure that students see value in them
• Use the class tests as opportunities to teach both content and practical skills related to the online system
• Provide well trained and motivated tutors to run the face-to-face tutorial sessions
• Arrange for dedicated tutorial spaces and times on the official timetable
• Minimise the number of lecturers who engage with the students to ensure ownership and building of relationships

The eight learning units were released strategically and sequentially to allow for design and re-design of subsequent units based on our learning during each iteration. In other words, after unit one we re-designed based on what we had learned and then set up unit two with revised design principles. Each unit could not remain as it was previously and a concerted effort was made to include content related to technologies that can play a role in the everyday functioning of the 21st century teacher. Some draft design principles related to learning technologies and the role of the 21st century teacher include:

• Remain relevant at all times
• Provide content that is meaningful (authentic) and up to date
• Include scenarios that engage students about the future
• Provide a variety of possible tools, services and Apps that can be used for each role of the teacher in the 21st century
• Allow for student choice regarding which tools, services and Apps they can use

Naturally, the design principles evolved as the units progressed and were refined accordingly after each iteration.

FINDINGS AND DISCUSSION: DESIGN PRINCIPLES FOR STUDENT SUCCESS

Firstly, the initiative to take over and re-vamp the module was taken on by a single division of the Department of Science and Technology Education within the Faculty of Education. This Learning Technologies Unit (LTU) has been largely successful in giving the module an identity and a conceptual “home”. By putting a distinctive learning technology slant to the module it has been an easy transition to remain current and address issues that lead students into the fourth industrial revolution (4IR). The 21st century skills topic has also ensured that students are not simply focusing on teaching in general, but also on the skills and tools needed to succeed in their future teaching. For this reason, a future oriented approach which focuses on what teaching “could be” has also been found to be engaging and relevant for the students. By focusing on redesigning the module content, and including detail on the teacher in the 21st century in all units, we provided a fresh focus that aligns well with the notion of the teacher in the 4IR.

By reducing the lecturer numbers from seven to three, and by ensuring that they all came from a single division at the university, we have further strengthened the identity of the module as a topical and relevant experience. Students appear to be more eager and willing to engage with the revised topics that seem to be more meaningful to them than before. Students seem to appreciate the more structured approach, along with the more meaningful
subject matter, and are also happier with the relationships that can be built with the reduced number of lecturers.

The new module coordinator along with the lecturing team have reconceptualised the online component to include relevant content and additional reading and exercises for students at all “levels”. The units appear to include a lot of content online but there are always students who need to be stretched a little with additional engagement. It is our feeling that this “extra” content may inspire those students who normally do the bare minimum to get more involved. Content includes text, journal articles, links to web sites, downloaded content, videos, and graphics. As mentioned before, each unit now also includes 21st century skills and technologies that can be used by the teacher in the 4IR, with a focus on tools, Apps and online services.

A consistent assessment approach was implemented throughout the 2019 intervention to address previous problems related to assessment. The assessment strategy this year included a revised and updated online quiz format. This format was replicated in the online examination that mirrors the online multiple choice tests that were implemented after each unit. The only difference between the tests and the examination was that the examination was held in a computer venue under supervision. Test banks (pools) were compiled for this function and questions were randomly selected from the pools in each of the four examination sections. Each section had 25 random questions from the pools. The four sections were created to prevent the loss of all work due to student errors or system failure on the day of the examination. It was also done to allow students to submit sections randomly to reduce strain on the network. The consistent approach to assessment was well-received and also reduced the stressful task of physical marking for the lecturers. This does not mean that there is no work to be done. On the contrary, the setup of the online quiz takes a long time and will constantly need to grow and improve. The only difference here is that the lecturer will do the work before the assessment rather than after.

A teaching evaluation and a module evaluation done by independent institutional researchers on this priority module has provided positive feedback in all regards. The only aspect that needs to be tightened up in the next year is the provision of more adequate feedback in the online assessments to facilitate learning as well as additional practice for the online quiz section.

The draft design principles briefly mentioned in this article will now be refined and tested once again in the new intake in 2020. The DBR process continues and ultimately I will go back to theory again to verify certain design principles or to suggest new contributions to theory in a specific context. Through this process, I have also attempted to address the notion of socially responsible research (Reeves, Herrington & Oliver, 2005) by addressing the quality of pre-service teacher training, especially those problems related to teaching and learning in the 21st century and teacher development in general. The technological tools and 21st century skills that are needed in the 4IR also receive the necessary attention. For this reason, in this study there is potential to make a contribution to both educational theory and teaching practice. More importantly, this can be seen as meaningful research that is socially responsible, with a high theoretical and practical value. This is not only socially responsible research but also “educationally relevant research” (Reeves, Mckenney & Herrington, 2011).

REFERENCES


ABSTRACT – Scale items related to Cognitive and Metacognitive Strategies (CMSs), Course Design Characteristics (CDCs), Knowledge Sharing Behaviour (KSB) and Innovative Behaviour (IB) can be gathered from literature and located within relevant theoretical conceptual frameworks. The aim of the study reported on in this paper was answering the research question: How can such items be re-purposed and/or modified for measuring CMSs, CDCs, KSB and IB during technology education? The importance of this research is justified in terms of the study objectives. The paper explains the design and execution of the methodology as appropriate and adequate in relation to the research question. This quantitative research design considered issues of reliability and validity. The discussion of results shows insight and originality, suggests implications and makes recommendations that are applicable and useful. The research question is answered in the conclusion, with the conclusions being justifiable in terms of the methodology and the results of the pilot study, which allowed for refining of the measures in terms of a set of original items to be used in the main study. The pilot study also contributes towards scholarly debate in fields related to CMSs, CDCs, KSB and IB.

Keywords: Innovative Behaviour (IB), Technology Students

INTRODUCTION

Problem context description

Many individual items on Likert-type scales related to Cognitive and Metacognitive Strategies (CMSs), Course Design Characteristics (CDCs), Knowledge Sharing Behaviour (KSB) and Innovative Behaviour (IB) can be gathered from an extensive literature review, as outlined in the latest and most relevant research findings on these topics.

As explained in greater detail in the next section of this paper, the scale used in this study to measure IB was based on that of Hartjes (2010), who investigated the alignment of employee competences with the organizational innovation strategy, while Morgeson and Humphrey (2006) developed and validated the Work Design Questionnaire (WDQ) as a comprehensive measure for assessing job design and the nature of work. As the latter was adapted to measure CDCs, the current limitations resulted in a need to ensure that the adaptations made in order to measure these properties with regard to students did not interfere with the reliability and validity of measurements. Especially the Motivated Strategies for Learning Questionnaire (MSLQ), used towards measuring CMSs (Pintrich, Smith, Garcia, & McKeachie, 1991), Morgeson and Humphrey (2006), as well as the measure of KSB by Yi (2009), were all published more than ten years ago – the continued relevance of these for 21st century students also needed to be confirmed.

The aim of the pilot study reported on in this paper therefore was to answer the research question: How can such items be re-purposed and/or modified for measuring the effects of CMSs, CDCs and KSB on the development of innovative behaviour during technology education?

Like the problem statement of Goosen and Ngugi (2018, p. 377), this study sought to discover a structural equation model “to elucidate the complex nature of” relationships through a better understanding of how knowledge sharing behaviour and its contextual antecedents influence students’ propensity for innovative behaviour.

THEORETICAL BACKGROUND

Cognitive and Metacognitive Strategies

The MSLQ has two broad scales: those related to learning strategies and motivation (Pintrich, et al., 1991). The learning strategies scales had two components, namely resource management and cognitive and metacognitive strategies. The resource management strategies assumed four subscales: Time and study environment (8 items), effort regulation (4 items), peer learning (3 items), and help seeking (4 items).
Examples of items in the resource management strategies component include items such as “When studying for this course, I often set aside time to discuss the course material with a group of students from the class” on the ‘peer learning’ subscale. Similarly, for the ‘help seeking’ subscale, it had items such as “When I can’t understand the material in this course, I ask another student in this class for help”. From the wording of the question items, the two scales of ‘peer learning’ and ‘help seeking’ were deemed by the researcher to be associated with the mediating variable of KSB in the study reported on in this paper. Hence, the entire component of resource management strategies was not used. The study adopted the cognitive and metacognitive strategies component of the MSLQ. Informed by Pintrich, et al. (1991, p. v), the cognitive and metacognitive strategies component had 31 items: Rehearsal (4 items), elaboration (6 items), organisation (4 items), critical thinking (5 items), and metacognitive self-regulation (12 items). The original cognitive and metacognitive strategies component had the items arranged so as to mix up the questionnaire items across the subscales, and the same order was retained. The items in this scale was as indicated in Table 1 of Ngugi and Goosen (2019). There was no change to the cognitive and metacognitive strategies component and all 31 items in the scale were retained.

COURSE DESIGN CHARACTERISTICS

Especially the article by Parker, Van den Broeck and Holman (2017) seemingly acted as an update for the WDQ (Morgeson & Humphrey, 2006), with the former looking at work design influences in terms of a synthesis of multilevel factors that affect the design of jobs. Apart from Parker, et al. (2017), the task characteristic of autonomy has also received great attention in literature on motivational work design, like Battistelli, Montani and Odoardi (2013), who investigated the impact of feedback from job and task autonomy in the relationship between dispositional resistance to change and Innovative Work Behaviour (IWB).

Knowledge Sharing Behaviour
Recent studies, which have examined the concept of Knowledge Sharing Behaviour (KSB), include Tjoflåt, Razaonandriana, Karlsen and Hansen (2017) and Yi (2009). The latter author conceptualized in tabular form a comparison of the four components of knowledge sharing behaviour and highlighted the associated types of channel used and the type of knowledge involved. These four components of KSB in this study are hypothesized to act as mediators of IB individually and collectively.

Innovative Behaviour
Hartjes (2010) used a case study of employees in an organization, a cable factory in Twente in the Netherlands. There is vast literature on the concept of idea generation, including Monteiro, da Silva and Capretz (2016) describing their findings from a pilot case study on the innovative behaviour of software engineers. Some of the authors, who have applied the bootstrapping method in studies related to innovative behaviour, include Mahmood and Bakar (2016), who examined the moderating role of entrepreneurial self-efficacy in terms of strategic improvisation and performance relationships.

METHODOLOGY

Ngugi and Goosen (2017, p. 82) indicated that a “cross-sectional research design was employed” for exploring relationships between “constructs, as such a design” was deemed to be suitable for data obtained over a relatively short period of time (Creswell, 2014).

Data collection
Petersen, Louw, and Dumont (2009) commented on the aspect of questionnaire length, and posited that participants are more likely to be distracted, may skip some items, lose interest in filing the questionnaire and have less concentration, if the instrument is too long. Mowbray, Boyle and Jacobs (2014) further suggested that the questionnaire length increased respondents fatigue and subsequent response quality. Conversely, instruments that are relatively short tend to be less intimidating and respondents have a higher chance of
answering all the items in the scale in full. To make the questionnaire acceptable to respondents, by them taking an acceptable amount of time to complete the questionnaire, and retain all the exogenous and endogenous constructs, some scales were shortened, while others were designed to have a specified reduced number of items, in comparison to the full-scale measures.

**RESEARCH INSTRUMENTS**

In terms of the accuracy of input, out of range values and multiple response and multiple dichotomy analysis, care was taken to score in reverse order all negative-worded items, which had the net effect of having higher values representing higher levels of agreement with the questionnaire items (Coakes & STEED, 2003).

**Sampling**

The pilot study utilised a convenience sample of 38 respondents drawn from one private university, namely Mount Kenya University. Scale reduction analysis was used to generate the inter-item total correlation and Cronbach alpha reliability coefficients, as presented in Ngugi and Goosen (2017) and (2018).

**Research population**

A private university was chosen to avoid contaminating the sample population for the main study.

During the piloting stage, verbal discussion with the respondents suggested that the questionnaire length was intimidating, as it was too long and had several similar question items that appeared repetitive. Based on examining the item-to-total correlations values, the final questionnaire items were reduced. In addition, in order to enhance the content validity, academic staff in Information Technology programmes were requested to judge how well the items were a true representation of the principal constructs. New criteria for assessing discriminant validity in variance-based Structural Equation Modelling (SEM) were also sought (Henseler, Ringle, & Sarstedt, 2015).

One way to reduce the number of items in a variable is examining the item-total correlation. The coefficient alpha values for each dimension and the total scale were as presented in Table 1.

<table>
<thead>
<tr>
<th>Scale</th>
<th>Reliability (Cronbach’s Alpha)</th>
<th>No of items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovative Behaviour (IB)</td>
<td>.724</td>
<td>11</td>
</tr>
<tr>
<td>Knowledge Sharing Behaviour</td>
<td>.889</td>
<td>20</td>
</tr>
<tr>
<td>Cognitive and Metacognitive Strategies</td>
<td>.945</td>
<td>31</td>
</tr>
<tr>
<td>Course Design Characteristics</td>
<td>.852</td>
<td>44</td>
</tr>
<tr>
<td>• Task characteristics</td>
<td>• .819</td>
<td>• 5</td>
</tr>
<tr>
<td>• Knowledge characteristics</td>
<td>• .793</td>
<td>• 9</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>106</td>
</tr>
</tbody>
</table>

The reliability analysis for the innovative behaviour scale was as presented in Table 2.
Table 2: Reliability analysis for the innovative behaviour scale

<table>
<thead>
<tr>
<th>How often do you…</th>
<th>Scale Mean if Item Deleted</th>
<th>Scale Variance if Item Deleted</th>
<th>Corrected Item-Total Correlation</th>
<th>Cronbach’s Alpha if Item Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. …look for opportunities to improve an existing process, technology, product, or service?</td>
<td>32.93</td>
<td>39.456</td>
<td>.330</td>
<td>.710</td>
</tr>
<tr>
<td>2. …recognize opportunities to make a positive difference in IT software development, project development, class, or the society at large?</td>
<td>32.48</td>
<td>38.875</td>
<td>.471</td>
<td>.693</td>
</tr>
<tr>
<td>3. …pay attention to non-routine issues related to my course, class, department, or the market place for IT products?</td>
<td>33.07</td>
<td>43.764</td>
<td>.043</td>
<td>.748</td>
</tr>
<tr>
<td>4. …search out new IT methods, techniques, or instruments?</td>
<td>33.07</td>
<td>35.994</td>
<td>.466</td>
<td>.689</td>
</tr>
<tr>
<td>5. …generate original solutions to Information Technology problems?</td>
<td>33.22</td>
<td>34.564</td>
<td>.604</td>
<td>.665</td>
</tr>
<tr>
<td>6. …find new approaches to execute Information Technology tasks?</td>
<td>33.37</td>
<td>37.242</td>
<td>.479</td>
<td>.688</td>
</tr>
<tr>
<td>7. …encourage key class members to be enthusiastic about innovative ideas?</td>
<td>33.22</td>
<td>39.333</td>
<td>.291</td>
<td>.717</td>
</tr>
<tr>
<td>8. …attempt to convince people to support an innovative idea?</td>
<td>32.74</td>
<td>40.123</td>
<td>.268</td>
<td>.719</td>
</tr>
<tr>
<td>9. …systematically introduce innovative ideas into Information Technology course practices?</td>
<td>33.15</td>
<td>40.746</td>
<td>.271</td>
<td>.718</td>
</tr>
<tr>
<td>10. …contribute to the implementation of new ideas?</td>
<td>32.89</td>
<td>38.641</td>
<td>.422</td>
<td>.697</td>
</tr>
<tr>
<td>11. …put effort into the development of new things?</td>
<td>32.81</td>
<td>38.695</td>
<td>.455</td>
<td>.694</td>
</tr>
</tbody>
</table>

Although the scale was reliable and had met the cut off criteria for internal consistency reliability value of 0.7, some of the items (3, 7, 8 and 9) had low item-total correlations, below 0.3. A closer examination of the items revealed the need to reword the items. The new item was thus reworded as follows “pay attention to non-routine issues related to my project in software development”. The IB scale had 2-3 items per variable, which was acceptable, and the scale was not reduced.

The reliability analysis for the knowledge sharing behaviour scale was as presented in Table 3. The negative values of the item-total correlations for questionnaire items 2 and 3 were due to negative wording. The low values of the item-total correlation, however, demanded that items 1, 2 and 3 be deleted.

The reliability analysis for the task characteristics subscale was as presented in Table 4. Five items (1, 4, 6, 14 and 17) had item-total correlations below 0.25 and were excluded from the study. Although items 2 and 3 also had low item-total correlations, they were retained, as their low item-to-total correlation was thought to be related to the reverse wording in the questionnaire items. Removal of the negatively correlated item 1 was expected to resolve problems in measurement of the autonomy subscale of the task characteristics subscale. The item “The project work is arranged so that I can do a complete piece of work from beginning to end” was also deleted, as it had an item-total correlation of 0.295 and was similar in meaning to item “the project work involves completing a piece of work that has an
obvious beginning and end”. Finally, the item “the project work requires that I only do one task
or activity at a time” was also deleted.

**DISCUSSION OF RESULTS**

Based on the information gathered during the piloting stage, it was noted that some the
subscales had too many items, and/or some, which were repetitive. One critical case was
three of the subscales of KSB, which had eight or seven items respectively. The course
design characteristics scale also had a total of 44 items, from the two subscales of task and
knowledge characteristics.

**Table 3:** Reliability analysis for the knowledge sharing behaviour scale

<table>
<thead>
<tr>
<th>How often do you…</th>
<th>Scale Mean if Item Deleted</th>
<th>Scale Variance if Item Deleted</th>
<th>Corrected Item-Total Correlation</th>
<th>Cronbach’s Alpha if Item Deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ...submit documents and reports to lecturers?</td>
<td>58.92</td>
<td>225.993</td>
<td>.053</td>
<td>.898</td>
</tr>
<tr>
<td>2. ...share findings in class journals, magazines, or newsletters?</td>
<td>59.75</td>
<td>231.152</td>
<td>-.058</td>
<td>.898</td>
</tr>
<tr>
<td>3. ...share documentation from personal files related to current Information Technology course?</td>
<td>59.38</td>
<td>230.071</td>
<td>-.035</td>
<td>.899</td>
</tr>
<tr>
<td>4. ... contribute ideas and thoughts to class online forums?</td>
<td>60.25</td>
<td>213.413</td>
<td>.567</td>
<td>.883</td>
</tr>
<tr>
<td>5. ...keep others updated with important technological information through online discussion boards?</td>
<td>59.38</td>
<td>201.375</td>
<td>.637</td>
<td>.879</td>
</tr>
<tr>
<td>6. ...express ideas and thoughts in class /technological discussions?</td>
<td>59.17</td>
<td>206.754</td>
<td>.644</td>
<td>.880</td>
</tr>
<tr>
<td>7. ...propose problem-solving suggestions related to my studies?</td>
<td>59.13</td>
<td>206.636</td>
<td>.620</td>
<td>.880</td>
</tr>
<tr>
<td>8. ...answer questions of others in class meetings and other forums?</td>
<td>59.29</td>
<td>209.259</td>
<td>.535</td>
<td>.882</td>
</tr>
<tr>
<td>9. ...share success stories that may benefit the class?</td>
<td>58.92</td>
<td>204.601</td>
<td>.624</td>
<td>.880</td>
</tr>
<tr>
<td>10. ...reveal past personal failures or mistakes in class /technology meetings to help others avoid repeating these?</td>
<td>59.08</td>
<td>201.732</td>
<td>.646</td>
<td>.879</td>
</tr>
<tr>
<td>11. ...have online chats (e.g. Facebook, Twitter, Hangouts) with others to help them with their technology -related problems?</td>
<td>58.46</td>
<td>197.998</td>
<td>.654</td>
<td>.878</td>
</tr>
<tr>
<td>12. ...share ideas and thoughts on specific topics through email communication?</td>
<td>59.21</td>
<td>200.955</td>
<td>.635</td>
<td>.879</td>
</tr>
<tr>
<td>13. ...spend time in personal conversation (e.g. discussion over breaks, through telephone) with others to help them with their course-related problems?</td>
<td>59.50</td>
<td>216.609</td>
<td>.396</td>
<td>.886</td>
</tr>
<tr>
<td>14. ...keep others updated with important class /technological information through personal conversation?</td>
<td>58.96</td>
<td>206.911</td>
<td>.658</td>
<td>.879</td>
</tr>
<tr>
<td>15. ...share passion and excitement on some specific subjects with others through personal conversation?</td>
<td>58.75</td>
<td>209.326</td>
<td>.482</td>
<td>.884</td>
</tr>
<tr>
<td>16. ...share experiences that may help others avoid risks and trouble through personal conversation?</td>
<td>58.75</td>
<td>199.065</td>
<td>.689</td>
<td>.877</td>
</tr>
<tr>
<td>17. ...meet with classmates and other IT techies to create innovative solutions for problems related to our studies</td>
<td>59.42</td>
<td>203.471</td>
<td>.655</td>
<td>.879</td>
</tr>
</tbody>
</table>
18. …meet with classmates and other IT techies to share own experience and practice on specific topics with common interests?  
   Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted
   59.46 | 204.346 | .593 | .880

19. …meet with classmates and other IT techies to share success and failure stories on specific topics with common interests?  
   Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted
   59.75 | 203.674 | .668 | .878

20. …support development of IT skills for my classmates and others?  
   Scale Mean if Item Deleted | Scale Variance if Item Deleted | Corrected Item-Total Correlation | Cronbach's Alpha if Item Deleted
   58.83 | 211.449 | .497 | .884

<table>
<thead>
<tr>
<th>Table 4: Reliability analysis for the task characteristics subscale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Mean if Item Deleted</td>
</tr>
<tr>
<td>----------------------------</td>
</tr>
<tr>
<td>1. The project work allows me to make decisions about how to schedule my project/studies</td>
</tr>
<tr>
<td>2. The project work allows me to decide on the order in which things are done</td>
</tr>
<tr>
<td>3. The project work allows me to plan how I do my studies</td>
</tr>
<tr>
<td>4. The project work gives me a chance to use my personal initiative or judgment in carrying out related tasks</td>
</tr>
<tr>
<td>5. The project work does allow me to make a lot of decisions on my own</td>
</tr>
<tr>
<td>6. The project work provides me with significant autonomy in making decisions</td>
</tr>
<tr>
<td>7. The project work allows me to make decisions about what methods I should use to complete my project/studies</td>
</tr>
<tr>
<td>8. The project work gives me considerable opportunity for independence and freedom in studies</td>
</tr>
<tr>
<td>9. The project work allows me to decide on my own how to go about doing the work</td>
</tr>
<tr>
<td>10. The project work involves a variety of tasks related to project/studies</td>
</tr>
<tr>
<td>11. The project work involves doing a number of different things</td>
</tr>
<tr>
<td>12. The project work does require the performance of a wide range of tasks</td>
</tr>
<tr>
<td>13. The project work involves performing a variety of IT tasks</td>
</tr>
<tr>
<td>14. The project work is likely to significantly affect the lives of other people</td>
</tr>
<tr>
<td>15. The project work itself is very significant and important in the broader scheme of things</td>
</tr>
<tr>
<td>16. The project work has a large impact on people outside the class</td>
</tr>
<tr>
<td>17. The project work has a significant impact on people outside the class</td>
</tr>
<tr>
<td>18. The project work involves completing a piece of work that has an obvious beginning and end.</td>
</tr>
<tr>
<td>19. The project work is arranged so that I can do a complete piece of work from beginning to end.</td>
</tr>
<tr>
<td>20. The project work provides me the chance to completely finish the pieces of work</td>
</tr>
</tbody>
</table>
21. The project work does allow me to complete what I start. & 72.35 & 66.692 & .342 & .814 \\
22. The technological activities provide direct and clear information about the effectiveness of my project. & 71.30 & 62.676 & .688 & .797 \\
23. The project work itself provides feedback on my performance. & 71.48 & 66.170 & .451 & .808 \\
24. The project work itself provides me with information about my performance & 71.26 & 64.565 & .618 & .801 \\
25. The project work requires that I only do one task or activity at a time & 72.04 & 67.680 & .301 & .815 \\

<table>
<thead>
<tr>
<th>Table 5: Reliability analysis of knowledge characteristics subscale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale Mean if Item Deleted</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>1. The tasks are simple and uncomplicated</td>
</tr>
<tr>
<td>2. The project work comprises relatively complicated tasks</td>
</tr>
<tr>
<td>3. The project work involves performing relatively simple tasks</td>
</tr>
<tr>
<td>4. The project work requires me to monitor a great deal of information.</td>
</tr>
<tr>
<td>5. The project work requires that I engage in a large amount of thinking.</td>
</tr>
<tr>
<td>6. The project work requires me to keep track of more than one thing at a time.</td>
</tr>
<tr>
<td>7. The project work does require me to analyse a lot of information.</td>
</tr>
<tr>
<td>8. The project work involves solving problems that have no obvious answer.</td>
</tr>
<tr>
<td>9. The project work requires me to be creative.</td>
</tr>
<tr>
<td>10. The project work often involves dealing with problems that I have not met before.</td>
</tr>
<tr>
<td>11. The project work requires unique ideas or solutions to problems.</td>
</tr>
<tr>
<td>12. The project work requires a variety of skills.</td>
</tr>
<tr>
<td>13. The project work requires me to utilize a variety of different skills</td>
</tr>
<tr>
<td>14. The project work does require me to use a variety of complex or high-level skills.</td>
</tr>
<tr>
<td>15. The project work requires the use of a number of skills.</td>
</tr>
<tr>
<td>16. The project work is highly specialized in terms of purpose, tasks, or activities</td>
</tr>
</tbody>
</table>
The tools, procedures, materials used in my study are highly specialized in terms of purpose.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>The project work requires very specialized knowledge and skills.</td>
<td>49.57</td>
<td>53.057</td>
<td>.224</td>
<td>.791</td>
</tr>
<tr>
<td>18</td>
<td>The project work requires a depth of knowledge and expertise.</td>
<td>49.52</td>
<td>49.962</td>
<td>.306</td>
<td>.789</td>
</tr>
</tbody>
</table>

The results of scale reduction using Cronbach alpha reliability analysis, with a focus on items with low item-to-total correlation, in terms of the scales, subscales and number of items in the reduced versions were as indicated in Tables 6 to 8.

These final items were selected based on content and face validity, as well as items highlighted by low and/or negative scores for item-to-total correlation scores. This had the effect of increasing the quality of responses and the completion of items significantly. Furthermore, the questionnaire items were presented on two A4 size papers that were printed on both sides, so as not to intimidate respondents.

During the pilot, each of the four KSB sub-constructs had five items each. The reduction in the number of items from 20 to 16 was significant, representing a decrease of 25% (see Table 6).

Table 7 shows that the reduction in the number of task characteristics items from 24 to 17 represented a decrease of 29%, which was significant. After the pilot, the autonomy section had six items, composed from Scheduling Autonomy, Decision-Making Autonomy, and Methods Autonomy. The other sections had either two or three items each.

The reduction in the number of knowledge characteristics items (see Table 8) from 20 to 12.

**Table 6:** Items in the reduced version of the knowledge sharing behaviour scale.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>No of Items in Yi (2009)</th>
<th>No of Items used in Pilot</th>
<th>No of Items in Reduced Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Written Contributions</td>
<td>5</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Class Communications</td>
<td>8</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Personal Interactions</td>
<td>8</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Communities of Practice</td>
<td>7</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>20</td>
<td>16</td>
</tr>
</tbody>
</table>

**Table 7:** Items in the reduced version of the task characteristics subscale.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Original No of Items</th>
<th>No of Items in Reduced Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scheduling Autonomy</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Decision-Making Autonomy</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Methods Autonomy</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Task Variety</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Task Significance</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Task Identity</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Technology Feedback</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>24</td>
<td>17</td>
</tr>
</tbody>
</table>
Table 8: Items in the reduced version of the knowledge characteristics subscale.

<table>
<thead>
<tr>
<th>Subscale</th>
<th>Original No of Items</th>
<th>No of Items in Reduced Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Information</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Solving</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Skill Variety</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Specialization</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>13</td>
</tr>
</tbody>
</table>

represented a decrease of 35%, which was significant. The Complexity and Information Processing sections had items reduced from eight to four (50%).

CONCLUSION

Linking the results to concepts from the theoretical framework, the pilot study reported on in this paper contributes to scholarly debate in fields related to cognitive and metacognitive strategies, course design characteristics, knowledge sharing behaviour and innovative behaviour, supporting arguments in favour of the mutual interrelationships between these variables in earlier research, as well as confirming that the revised items in the context of the current study also retain these.

The research question is answered in this conclusion, with the conclusions being justifiable in terms of the results of the pilot study, which allowed for refining of the measures in terms of a set of original items to be used in the main study: The four latent variables of the study ended up containing 88 Likert scale question items, which respondents were requested to answer, categorised into four Likert scales. In terms of the justification of the methodology used, the most important concern and challenge was how to increase the response rate, through a meticulous examination of the questionnaire length and total time required to answer the items.

In terms of increasing the depth of research, the authors wish to point out that Analysis of Moment Structures (AMOS) had been widely used in SEM research that includes missing data, as it provides estimates that are efficient and consistent, due to its use of Full Information Maximum Likelihood (FIML) estimation (Henseler, et al., 2015).

The significance of the refined questionnaire items is justified in terms of the objectives of the pilot study, which included to measure the reliability and explore the face validity of the suggested scales, ensure that the final questionnaire was of reasonable length, increasing participation rates, and reduce the possibility of errors caused by respondent fatigue, or declining interest.

Some items in the motivation scales of the MSLQ were deemed by the researcher to be closely related to the task characteristics subscale of the CDCs scale. For instance, the Task Value subscale had items such as “I think the course material in this class is useful for me to learn”, which closely relates to the task characteristics subscale of the present research. Hence, the motivation scales were not used as a subscale. Regarding making recommendations that are applicable and useful, there may be scope for further research to explore the relationship between these variables of the motivational scales and the task characteristics subscale used in the present research.

REFERENCES


Hartjes, B. (2010). Aligning employee competences with organizational innovation strategy: A case study at B.V. Twentsche Kabelfabriek. Enschede: University of Twente.


ABSTRACT:
This study investigated the effects of a Multimedia Computer Instructional Package (MCIP) on Technical and Vocational Education and Training (TVET) College students’ understanding of mechanical properties of steel. The MCIP was designed in assumption that it will engage students actively in the learning activities for this study. Active participation in the learning process was one the guiding principle of constructivist learning which underpinned the theoretical framework of this study. The study was conducted with ninety nine students from four public TVET Colleges in the Eastern Cape Province of South African. Intact groups of four Material Technology classes from four different colleges were selected. The four classes were randomly assigned to experimental and control groups. National Qualification Framework (NQF) level three students enrolled for Engineering Related and Design (ERD) Programme were used for the study. Quasi-experimental design with pre-test post-test non-equivalent intact groups was used. An intervention was done in two weeks. Instructional strategies for the intervention were done in two ways; the use of MCIP and the use of Conventional Method of Instruction (CMI). Data was collected from the pre and post-test. Independent sample t-test was conducted to test the null hypothesis. The result shows that students taught with MCIP (Experimental Group: n=48) performed better in mechanical properties of steel (t = 2.954, DF = 95, and p < 0.05) than students taught in CMI (Control Group: n=51).

KEYWORDS:
Understanding, Constructivism, Mechanical Properties of Steel, Multimedia Computer Instructional Package

INTRODUCTION
TVET education systems are fundamentally shaped to address high unemployment rate and to open the doors of economic acceleration in many countries (Bhurtel, 2015). Example, TVET education system in Singapore and Netherlands produce world class technical skills workforce (Seng, 2011). Unfortunately the story is different in South African TVET colleges system. According to Mmako, Schultz and Cecile (2016, 144), South African TVET colleges are faced with lots challenges. The challenges include capacity to deal with increasing number of student's enrolment and competency for coping with large and mixed ability students. One of the main criticisms of the National Certificate Vocational (NCV) programmes in South African TVET colleges is its confusing admission policies. According to the White Paper report for Post-School Education and Training admission policies, student who passed Grade 9 only and students who had finished schooling (National Senior Certificate (NSC) holder) are allowed to be in the same class and do the same subject (DHET, 2013). Dealing with this mixed ability classes (students from vastly different educational levels and mostly from poor socioeconomic status in the same class) has made teaching difficult for lecturers and also created learning dissatisfactions among students. This has caused a high dropout of students in the TVET sector, especially at the entry level (NCV level 2).

Developing a learning programme that can suit this mixed ability classes at TVET colleges will certainly be an important endeavour. Multimedia learning programme is an innovative way to make learning more dynamic, longer lasting, and more applicable to the world outside the classroom (Almarabeh, Amer & Sulieman, 2015). Learning through multimedia package creates an active learning process on which this study was articulated. Multimedia learning package stores retrieves and presents audio, video, graphics and textual information in way that stimulate learning interest. It also has a potential s to generate a positive impact on the learner’s problem solving abilities (Rosa & Preethi, 2012). Previous studies on multimedia
learning programmes largely focused on self-guided multimedia learning programmes but this present study focus pre-training principle. It is also important to note that there is fundamental difference in the ways in which males and females process information from these two modes (multimedia and conventional) of presentation (Liu et al, 2015). Information society has not responded equitably to address the needs of men and women in learning through the use of digital information (Wangmo, Violina & Haque, 2004).

THEORETICAL BACKGROUND

Therefore the theoretical frameworks that underpinned this study are as follows.

Universal design for Learning (UDL)

UDL framework ensures that learners have multiple means to engage in learning, are given the information and content instruction through multiple modalities, and have an opportunity to demonstrate their learning via multiple means (Hollingshead, 2017) It is a validated framework for addressing students with different learning abilities (Meyer et al., 2014). Selection of learning materials and learning activities for the MCIP were made in line with learning goal and also to accommodate learners with competing attentions. The modality of presentations in the package (MCIP) was also carefully designed to accommodate learners with mixed abilities.

Multimedia Cognitive Load theory

According to this theory, cognitive overload impair learning. Cognitive overload was avoided in the development of the MCIP by using only the relevant terminology for mechanical properties of steel, relevant images and simplified 3D motion pictures were used for lesson presentations. Technology that posed a threat of distracting learner from the learning goals was carefully eliminated from the design. Learning activities in the package were also carefully selected with aim to achieved the learning outcomes

Pre-Training Principles

People learn more deeply from multimedia instructional packages when they receive pre-training in the key words and brief summary on the contents of the lesson (Meyer, 2011b). This study focused on the teacher-guided instructional package (pre-training principle); in this case, the teacher introduced the basic concepts of the lesson and key words involved in the lesson before using the package. The teacher also guided the students throughout the lessons. MCIP was used as a teaching aid for teachers.

MECHANICAL PROPERTIES OF STEEL

An understanding of the basic mechanical properties of steel (MPS) is crucial to the understanding of Materials Technology as a subject at Technical and Vocational Education and Training (TVET) Colleges. MPS deal with internal responses of steel to external loads (MSE 209, 2010). These mechanical properties depend upon the microstructure and various types of steel. Kumar (2016) defines MPS as a "relationship between steel response or deformation of steel to an applied load (force), considering factors such as nature of the applied load and time, as well as the environmental conditions." Describing how steel deform (elongate, compress, twist) or break as a function of applied load (force) and time is critical to understanding the MPS and this concept is very difficult and abstract to explain to students even by the subject lecturers at TVET Colleges. Many researchers have reported on students’ difficulties in understanding the mechanical properties of steel (Heckler & Rosenblatt, 2010a). Some of the difficulties identified by Heckler and Rosenblatt (2010a) at Ohio State University in Columbus are as follows: Difficulties in differentiating stress and force, stiffness and strength, difficulties in the microscopic nature of metal and finding the Young's Modulus from a stress / strain plot. Krause, Decker, Niska, Alford and Griffin (2003) reported that students often find the concept of plastic deformation of steel too difficult and trace its origin to misconception student have on the atomic mechanism of steel deformation.
Heckler and Rosenblatt (2011) reported that many students conflate concepts such as ductility, strength and elasticity, and this difficulty is manifest in the reading of stress-strain curve graphs. Krause et al., (2003) reported that students find the principle of plastic deformation of steel too difficult and often believe that only plastic (thermoplastic or related material) undergo plastic deformation. At the time of this study and to the best knowledge of the researcher, there were no research reports on the context of materials technology at South African TVET Colleges available to the researcher.

A "Materials Concept Inventory (MCI)" was developed to evaluate a basic conceptual understanding of some concepts in materials science (Krause et al., 2003), but the MCI does not fit well with the Materials Technology syllabus at South African TVET Colleges.

This study designed, developed and investigated the effect of a multimedia computer instructional package on TVET college students' understanding of the mechanical properties of steel. The findings from the study will be useful to low experienced students (students admitted with a Grade 9 result and those who have been out of school for a long period before admission) to cope with the syllabus of materials technology. It will also motivate experienced students (National School Certificate holders) to perform better in the subject and help lecturers to manage classes with mixed abilities. Therefore, the following null hypotheses were set as a guideline to achieve this aim:

- There is no statistically significant difference on students’ achievement on higher order questions in mechanical properties of steel between those taught with Multimedia Computer Instructional Package and those taught in Conventional Method of Instruction.
- There is no statistically significant difference between the mean scores of the group taught with a Multimedia Computer Instructional Package and those taught in a Conventional Method of Instruction in post-test.
- There is no statistically significant difference in the mean scores of male and female students taught with a Multimedia Computer Instructional Package in post-test.

METHODOLOGY

This study used quantitative research methods and quasi-experimental design with a pre-test post-test non-equivalent groups design. NQF level 3 TVET College Students of materials technology from four (4) public TVET Colleges in the Eastern Cape Province were used. The existing classes (groups) for materials technology were used to avoid disrupting the college teaching timetable, therefore complete random sampling was not suitable for the study. The groups were randomly assigned to experimental and control groups. The threat to internal validity of selection was ruled out by comparing both groups with a pre-conceptual achievement test (Pre-test) in mechanical properties of steel in order to determine the equality of both groups (Vockell, 1983). The summary of the research design is shown in Figure 1.
SAMPLE AND SAMPLING TECHNIQUES
In selecting TVET Colleges in the Eastern Cape Province to participate in the study, purposive sampling and simple random sampling techniques were used. Purposive sampling relies on the judgment of the researcher. Certain criteria such as colleges with well-equipped computer lab and experienced lecturer were used for making selections.

SIMPLE RANDOM SAMPLING
The random sampling method was also used in selecting between the two groups of students (ARM and FT) to participate in the study. This was done by tossing COINS. The result of the exercise are summarised in Figure 2.
Development of Instruments
A conceptual achievement test (CAT) was used to test the hypothesis which guided the study. The test consisted of two sections. **Section 1** comprised of thirty questions, (twenty (20) multiple choice questions, five (5) one-word answer questions and five (5) true or false questions). It was developed to test students’ general knowledge of the mechanical properties of steel (MPS). **Section 2** of the CAT consists of two (2) essay questions, total of twenty marks to test students’ understanding of mechanical properties of steel. The test (section 1 & 2) covered the following concepts mechanical properties of steel: stress and strain curves, tensile testing, ductile, elasticity, plasticity, toughness, compressive strength, ultimate tensile strength and Young’s modulus of elasticity.

**Validity**
The Conceptual Achievement Test (CAT – Pre and Post-test) was developed from the curriculum content of Materials Technology for TVET Colleges in South Africa, strictly covered the topics mentioned above. The test (CAT) was validated by experienced materials technology lecturers and head of department (Engineering Studies). It was further piloted in one of the TVET colleges in the Eastern Cape Province of South Africa; the college was randomly selected from TVET colleges outside the study sample.

**Reliability**
The sets of the two scores (first and second test) were correlated and the results showed a high correlation of 0.98 which indicated a high consistency pattern in the students’ scores. Some students improved on their scores, changes in students marks were by a small margin (±3). The mean scores of students for the first and second test were also close to each other (eighteen and nineteen respectively). These scores indicated the test could be considered as a very reliable instrument.

**ETHICAL ISSUES**
The study complies with the following ethical guidelines:
The researcher sought the consent of all the participants (student and lecturers). Participants were given freedom to participate or decline, to continue or withdraw at any time, to respond or decline to the questionnaire. Guarantee of confidentiality of information and use of non-racial languages. No disruption of school timetable, programme and events.

**RESULTS**

<table>
<thead>
<tr>
<th>Index</th>
<th>STATISTIC IN PRE-TEST</th>
<th>STATISTIC IN POST-TEST</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control Group</td>
<td>Experimental Group</td>
</tr>
<tr>
<td>Number</td>
<td>51.00</td>
<td>48.00</td>
</tr>
<tr>
<td>Mean</td>
<td>20.18</td>
<td>18.77</td>
</tr>
<tr>
<td>Sum</td>
<td>1029</td>
<td>901</td>
</tr>
<tr>
<td>SD</td>
<td>7.30</td>
<td>6.80</td>
</tr>
<tr>
<td>Lowest Score</td>
<td>4.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Highest Score</td>
<td>37</td>
<td>32</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2: Mean and Standard Deviation (Male and Female) in the Experiment Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>Pre-CAT (Male)</td>
</tr>
<tr>
<td>Post-CAT (Male)</td>
</tr>
<tr>
<td>Pre-CAT (Female)</td>
</tr>
<tr>
<td>Post-test (Female)</td>
</tr>
</tbody>
</table>
Major Findings
Three null hypotheses were used to test the effectiveness of the MCIP and the results were as follows:

Null Hypothesis One:
Data collected from section 2 of the Post-CAT (Out of 20) was used to test null hypothesis one. Sections 2 of the test were high order questions in the mechanical behaviour of steel according to Bloom’s Taxonomy. The use of MCIP and Conventional Method of Instruction were the instructional strategies for the interventions. The result shows that the students taught with MCIP gained better understanding of mechanical properties of steel. The t-Test result revealed that there was a statistically significant difference between the two groups (Control and Experimental) leading to a rejection of null hypothesis one.

Null Hypothesis Two
An independent t-test revealed that there was no statistically significant difference between the two groups. Therefore null hypothesis (of no difference in mean scores between experimental and control groups) is accepted

Null Hypothesis Three
Comparing the mean score of both groups (male and female in experimental group) in Pre- and Post-CAT, the result showed that male students improved their performance more than the female students. An independent t-test conducted and the result revealed that there was no statistically significant difference between the two groups (male and female students), leading to the acceptance of null hypothesis three

DISCUSSION OF RESULTS
Higher order questions were used to test students understanding in mechanical properties of steel. The way students in the experimental group answered the questions demonstrate a good understanding of mechanical behaviour of steel. They also demonstrated a good ability to select different types of steels to suit different engineering designs. The result is in agreement with Almarabeh, Amer and Sulieman (2015) finding that multimedia learning package make learning more dynamic and promote lifelong learning. However there was is no statistically significant difference between the mean scores for the groups (control and experimental) leading to acceptance of null hypothesis two. Smaller sample used for this study might have affected the result. Larger sample was suggested for further studies.

Also male students in the experimental group performed better in mechanical properties of steel test than the female students in the same group. However, when looking at an individual performance, all the females in the experimental group improved their marks but not all the male students improved their marks, although some male students performed exceptionally well

CONCLUSION
This study developed a Multimedia Computer Instructional Packages (MCIP) and investigated its effect in understanding of mechanical properties of steel. The result shows that the packages (MCIP) help to improve students understanding in mechanical properties of steel. Students taught with an MCIP performed better than those taught in a conventional method of instruction in the Post-CAT in mechanical properties of steel. Finally, it was found that male students taught with MCIP performed better than female students taught with MCIP. Therefore the use of an MCIP was recommended as an effective teaching strategy at TVET Colleges, but further improvement in the sample size and the package were suggested.

RECOMMENDATIONS
The finding that the use of MCIP improves students’ understanding of MPS provided a possible platform for improving the MCIP to cover the entire curriculum in the materials
technology subject and provide further improvement in the design of the MCIP to achieve the learning goals for students.

It is, therefore, recommended for this study that Department of Higher Education and Training (DHET) Colleges invest money and time in developing multimedia instructional programmes such as the MCIP for all engineering subjects at TVET Colleges.

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