

Contents

Volume 10

2015

1.

Notes on contributors

4.

Editorial

Dolina Dowling

6.

The rationale for teaching Quantitative Literacy in 21st century South Africa: A case for the renaming of Mathematical Literacy

Ms Joan Houston, Umalusi, South Africa

Mr Simangele P. Tenza, Umalusi, South Africa

Ms Solante Hough, Crawford College, Pretoria, South Africa

Dr Rakesh Singh, al-Falaah College, Durban, South Africa

Dr Celia Booyse, Council for Quality Assurance in General and Further Education and Training (Umalusi), South Africa

37.

High school mathematics marks as an admission criterion for entry into programming courses at a South African University

Professor Duan van der Westhuizen, University of Johannesburg, South Africa

Mrs Glenda Barlow-Jones, University of Johannesburg, South Africa

51.

Social Development Theory:

A case for multilingual tutorials (MLTs) in Law

Advocate Noleen Leach, Cape Peninsula University of Technology, South Africa

69.

The notion of Lego® Mindstorms as a powerful pedagogical tool: Scaffolding learners through computational thinking and computer programming

Mrs Jacqui Chetty, University of Johannesburg, South Africa

85.

Stimulating and maintaining students' interest in Computer Science using the hackathon model

Dr Jabu Mtsweni, Council of Scientific and Industrial Research, South Africa & University of South Africa

Ms Hanifa Abdullah, University of South Africa

98.

Analysis of errors due to deficient mastery of prerequisite skills, facts and concepts: A case of financial mathematics

Mr Xolani Khalo, University of Fort Hare, South Africa

Professor Anass Bayaga, University of Zululand, South Africa

114.

Reflections on the NCS to NCS (CAPS): Foundation phase teachers' experiences

Professor Elize du Plessis, University of South Africa

Professor Petro Marais, University of South Africa

127.

Practitioners' Corner

Continuous Assessment in the Expressive Arts in Malawian Primary schools

Dr Grames Wellington Chirwa, University of Johannesburg, South Africa

Professor Devika Naidoo, University of Johannesburg, South Africa

141.

List of reviewers

Notes on contributors

Ms H. Abdullah is a senior lecturer at the University of South Africa (UNISA), lecturing in Business Information Systems and Computer Networks. She also supervises a number of Honours and Master's students and is currently working on her PhD thesis in the domain of Information Privacy Protection. Ms Abdullah is also pursuing research in ODL (Open Distance Learning) as well as in governance, risk management and compliance. As part of her community engagement, she has worked extensively in the Socially Relevant Computing flagship of the School of Computing (SoC). Ms Abdullah is actively involved in research and has produced a number of research outputs.

Mrs Glenda Barlow-Jones is a lecturer in the Applied Information Systems Department at the University of Johannesburg. She is currently completing her PhD in ICTs in Education. Her research identifies the challenges that students at higher education institutions experience while learning computer programming, and in particular challenges that emanate from the school education years preceding their enrolment. She has presented and published papers both nationally and internationally and has more than 18 years of higher education experience.

Presently, **Professor Anass Bayaga** is a research professor and Head of the Department of Mathematics, Science and Technology Education at the University of Zululand. Anass was previously a professor and the Faculty Research Co-ordinator of the Faculty of Education at the University of Fort Hare. His current interests are in two spectra, firstly: Actuarial Risk Analysis and Mathematics; specifically, Operations Research (Stochastic processes and Mathematical programming/optimisation), Actuarial & Financial Modelling (Analysis) and Neuro-Mathematics. Secondly, he is involved in Information Systems & Technology Risk with specific attention to: IT Operations Analysis (Systems development, Mobile & Educational technologies & Cloud computing), Security & Control (Biometric Technologies & Cryptosystems) and Data Analytics (Big Data). In terms of quality, sustainability and productivity of work, he has travelled, supervised masters and PhD candidates, researched and published extensively both in international and local journals.

Dr Celia Booysse is currently the Manager: Curriculum at Umalusi. She manages the curriculum quality assurance processes which include comparative research, triangulation, international benchmarking. She provides guidance in curriculum development. She also develops research tools for single evaluations, curriculum appraisals and to determine the level of productive thinking in practical assessment tasks. She is the co-author of three books on Curriculum Studies and her articles and conference papers cover a wide range of topics on curriculum, theoretical framing, instructional design and assessment practices, and thinking skill development.

Professor Elize du Plessis holds a DEd degree. She is an associate professor in the Department of Curriculum and Instructional Studies at the University of South Africa (UNISA) and has 25 years experience in distance teaching. She is the programme coordinator of the Post Graduate Certificate in Education (PGCE) (Senior phase and FET) programme. Her field of specialisation is Curriculum Development, Teaching and Learning and Distance Education. She is an experienced developer of course material for student teachers. She has written several chapters in books, authored and co-authored articles in non-accredited and accredited journals. She has presented papers at national and international conferences.

Mrs Jacqui Chetty is a lecturer within the Department of Applied Information Systems (AIS) at the University of Johannesburg (UJ). She is currently completing a PhD in IT Education with an emphasis on pedagogies for computer programming. Her research over the last five years has focused on improving students' problem-solving skills to prepare them better for the challenges related to learning computer programming. Her research has led her in the direction of innovative pedagogical tools that can further develop students' problem-solving skills. She has published both conference papers and journal articles at a national and an international level. Jacqui has also been collaborating with Stockton University (New Jersey, USA), where she will be conducting workshops regarding teaching problem solving at schools using innovative technological tools. She has also been involved with Lego Mindstorms robots projects both at university as well as at school level. Jacqui is passionate about introducing innovative pedagogies into the classroom that motivates students to improve their problem-solving skills as well as develop software solutions.

Dr Grames Chirwa is a postdoctoral research fellow in the Department of Education and Curriculum Studies in the Faculty of Education at the University of Johannesburg. His research interest is mainly in curriculum evaluation. He has served as a Curriculum Specialist for over 14 years at the national curriculum development centre in Malawi, the Malawi Institute of Education.

Ms Solante Hough is currently Acting Deputy Principal and Head of ICT at Crawford College Pretoria, where she teaches Mathematical Literacy and Social Media. Ms Hough has been employed at the College for the past 10 years. She has co-authored Mathematical Literacy textbooks as well as e-books from 2013 to 2015.

Ms Joan Houston is currently the team leader of the Mathematical Literacy Curriculum Research team for Umalusi. From 2009-2014 she was the team leader for the Umalusi Mathematical Literacy Post Examination Analysis team. She has been an independent consultant to the World Bank and Ministry of Finance of the Russian Federation (April 2015) on budget literacy, a teacher development consultant to JET in 2010, an education consultant to the Ford Foundation in Southern Africa as part of their Global Pathways to Higher Education initiative from 2004-2008, while simultaneously being coordinator, chief editor and author for Shutters first Grade 10-12 Mathematical Literacy textbook series. Her educational role was as Mathematics tutor then Programme Director for the Science Foundation Programme from 1993-2003 at the University of KwaZulu Natal.

Mr Xolani Khalo is currently completing his PhD in mathematics education at the University of Fort Hare and been engaged with mathematics didactics for the last five years. He works with the Eastern Cape Department of Education (ECDoE) and enjoys research and teaching at the Further Education Training (FET) band in South Africa.

Advocate Noleen Leach is the Interim Co-ordinator and co-founder of the Unit for Applied Law at the Cape Peninsula University of Technology. She holds an Honours degree in Education and a Master's degree in Law from the University of the Western Cape. She is the project leader for paralegal curriculum design at the Cape Peninsula University of Technology and has been admitted as an advocate of the former Cape of Good Hope Division of the High Court of South Africa. Her research interests span both law and education, with the focus on access to justice, the effect of labour legislation on small, medium and

micro enterprises (SMMEs), multilingualism in higher education and computer-based formative assessment in higher education. She is a recipient of the 2015 DPFD International Doctoral Social Science Research Council fellowship.

Professor Petro Marais is an associate professor in the Department of Early Childhood Development (ECD) at the University of South Africa (UNISA) and holds a DEd degree. She joined UNISA after being a teacher for several years. She specialises and lectures in ECD and has 22 years of experience in teaching practice through distance education. She is the programme coordinator of the BEd and PGCE qualifications in ECD. She has published several articles and chapters in books, presented numerous papers at national and international conferences and acted as supervisor for postgraduate students.

Dr Jabu Mtsweni is currently Senior Researcher and Cyber Security Specialist at the Council for Industrial and Scientific Research (CSIR) in the Defence, Peace, Safety and Security environment under the Cyber Defence Research Group. He is also an academic associate at the University of South Africa (UNISA), supervising over 10 Masters and PhD students, and an external/part-time Lecturer at Tshwane University of Technology (TUT) for postgraduate studies. Dr Mtsweni has over 12 years academic and industry experience and has published over 35 peer-reviewed conferences and journal papers/articles both in local and international forums. He is also a co-organiser of Random Hacks of Kindness in Pretoria and has participated in a number of hackathons and community engagements since 2010.

Professor Devika Naidoo is an associate professor in the Department of Education and Curriculum Studies at the University of Johannesburg. Her research interests include an analysis of curriculum, pedagogy and assessment from sociological perspectives. She has published several articles in national and international journals. Her current area of focus is post-school youth education in formal and informal contexts.

Dr Rakesh I. Singh is currently Head of Mathematics at Al-Falaah College, Dr Singh has taught Mathematics for the past 30 years at school level and tertiary level. He has been involved in curriculum writing for CASME, Masifundisane and ACE for UKZN (Mathematical Literacy Module). Dr Singh is the external Moderator for Umalusi (from 2010 to present) which requires quality assuring Senior Certificate Examinations for the Department of Basic Education, IEB and SACAI. He is also involved in writing up Curriculum Statements for NASCA (National Adult Senior Certificate). As a member of AMESA he has presented papers at regional conferences.

Mr Simangele P. Tenza has an MEd (University of KwaZulu-Natal) in Mathematics Education. He taught secondary school Mathematics for many years before joining CASME (Centre for the Advancement of Science and Mathematics Education) at UKZN, then joined the School of Education at UKZN as a Mathematics Education Lecturer, teaching undergraduate courses and at Honours and Masters level, before leaving at the end of 2009. He has been involved with Umalusi post-examination analysis and other related research projects since 2009. He has been a Mathematics and Mathematical Literacy Consultant for JET Education Services, working and mentoring FET teachers in various projects throughout South Africa. He has authored and co-authored Mathematical Literacy textbooks for Grades 10-12 which are currently recommended textbooks for the CAPS (Curriculum and Assessment Policy Statement).

Professor Duan van der Westhuizen is a professor of Learning Technologies at the University of Johannesburg. His primary fields of interests are Learning Technologies innovative teaching practices, authentic learning and design-based research methodologies. He is fiercely critical of the inappropriate use of learning technologies, and specifically when those are merely used to present content in digital format. He has served, or is currently serving, on a number of programme committees and editorial boards. He has significant postgraduate supervision experience, and approximately 50 masters students and 15 PhD students have graduated under his supervision.

Editorial

Dolina Dowling

Ten years ago *The Independent Journal of Teaching and Learning* was founded to provide a scholarly forum for academics and education practitioners to share their research in the broad area of teaching and learning. In 2014 the journal reached a milestone by being placed on the list of accredited journals by the South African Department of Higher Education and Training.

In the intervening years the journal has published articles in areas as diverse as *inter alia* transformation, quality assurance, foundation programmes, pedagogy, and access to higher education. This diversity and recurring topics like access with success, indicate a common theme underpinning the articles, i.e. the concerns of teachers, academics, and researchers about raising the quality of education provision at every level and their efforts to find ways to ensure that all students have a positive and successful learning experience.

More than 20 years after the advent of democracy in South Africa these issues have yet to be resolved. The fruits of democracy in particular with regards to quality higher education that includes access with success have not fully transpired for the most disadvantaged in South Africa. For instance, the 2012 graduation rates for undergraduate degrees and diplomas ranged from 15% to 25% at contact public universities whilst at UNISA it stood at 6% (*Statistics on Post-School Education and Training in South Africa: 2012*, Department of Higher Education and Training 2014: 14, Table 7). The benchmark set by the *National Plan for Higher Education* (Department of Education, 2001, 2.3) was 25% for contact institutions and 15% for distance learning institutions. Only one university reached the 25% target although a number were close.

These figures represent a missed opportunity for the youth of the country as well-educated citizens have a better quality of life in terms of physical and emotional health, interesting employment and work satisfaction than their less well-educated counterparts. It also detracts from the country's attempts to grow the economy and with it a prosperous civil society in which all citizens can creatively participate in its cultural, political and social life.

The need for access with success applies not only to higher education but also to all post-school education it is, as Minister Nzimande states, 'a major driver in fighting poverty and inequality in any society' (Preface to *White Paper for Post-School Education and Training*, 2013: viii).

This tenth volume is no exception to the previous nine in terms of purpose and diversity. It encompasses articles at all levels of education and within these there is further diversity. The first paper is an in-depth

research study on the Curriculum and Assessment Policy Statement for Mathematical Literacy as well as the defining features of Quantitative Literacy. The authors careful analysis and comparison of the skills and the content in these areas as well as their conclusions are useful for policymakers and educationalists alike. There is a need for citizens in the 21st century to be quantitatively literate so that they have the necessary problem-solving skills to function fully in society. The authors further conclude that Quantitative Literacy would be an appropriate admission requirement for study in the non-science disciplines at higher education institutions.

The following two articles deal with issues of admission to higher education programmes and access with success. One article investigates the use of mathematics high school marks as an admission criterion into computer programming courses at university and finds that they are not a measure of success and so are not a valid admission criterion. In the next paper the author addresses the thorny question of English being the medium of instruction in a multilingual country and the problems this presents for non-mother tongue English users. In an attempt to overcome this challenge the author carried out a pilot study using multilingual tutorials for first-year Law students in which the majority of the students' mother tongue language is isiXhosa or Afrikaans. She found that the use of multilingual tutorials improves student performance.

In the fourth and fifth articles the authors are concerned with ways to sustain interest and achieve success in learning in their respective disciplines in higher education institutions. In both articles innovative methods are used to achieve this. In the first of these, the author's research focus was on the use of robotics - Lego® Mindstorms robots - as a pedagogical tool for computer programming. The results of her case study showed that this was helpful both in the development of students' problem-solving skills and in making learning enjoyable. In the other article, the authors dealt with the problem of the low take-up of students to study computer science. Using the hackathon model as a case study, the authors found that this proved to be a good tool to both arouse and sustain students' interest in this discipline.

The last three articles deal with a variety of matters in school education. In the first, the authors investigated the types of errors made by Grade 10 learners in financial mathematics, and why they make them. Their research found that the errors made are not due to a lack of prerequisite skills, facts and concepts but rather to not reading instructions and not rounding off to the correct decimal places correctly. Mechanisms need to be put in place to ameliorate this. Nevertheless, this research would need to be replicated considerably before its conclusions can be generalised.

The next article deals with policy in which the authors use qualitative research methodology to investigate whether or not the revised National Curriculum Statement (NCS) Curriculum and Assessment Policy Statement (CAPS) is an improvement on the original NCS. Implementation of the amended NCS (CAPS) is shown to be a challenge.

Lastly, in *Practitioners' Corner*, the authors explore the implementation of continuous assessment policy in the Expressive Arts in Malawian primary schools. Their research shows how policy faces challenges in implementation due to amongst other things, scarce resources, and insufficient teacher training and support. Their findings serve as a reminder for all education policy makers that without an implementation strategy and adequate resources, physical, financial and human as well as effective monitoring and evaluation that irrespective of how well formulated a policy is, implementation is unlikely to be successful.

The rationale for teaching Quantitative Literacy in 21st century South Africa: A case for the renaming of Mathematical Literacy¹

Joan Houston, Umalusi, South Africa

Simangele P. Tenza, Umalusi, South Africa

Solante Hough, Crawford College, Pretoria, South Africa

Rakesh Singh, Al-Falaah College, Durban, South Africa

Celia Booyse, Council for Quality Assurance in General and Further Education and Training, South Africa

ABSTRACT

In 2014 Umalusi (Council for Quality Assurance in General and Further Education and Training) proposed research into Mathematical Literacy to determine whether the content and skills in Mathematical Literacy compare with the problem-solving skills considered necessary to be quantitatively literate by world standards. The team of researchers transformed this question into three questions.

1. What is Quantitative Literacy? What are its main characteristics (i.t.o. knowledge, skills and attitudes)?
2. Does Mathematical Literacy cover the skills considered to be necessary to be quantitatively literate by world standards?
3. To what extent does the Curriculum and Assessment Policy Statement (CAPS) for Mathematical Literacy encompass the skills and knowledge required for arithmetical / mathematical / quantitative problem solving with respect to content, depth and breadth?

The paper answers these three questions in depth using an extensive literature survey of writing about Quantitative Literacy as it is described internationally. The mathematical content and skills of Mathematical Literacy are compared to the internationally equivalent subjects, both in breadth and depth. A reflection follows on the effectiveness of these skills to equip students to solve real-life quantitative problems in the 21st century as well as to be a reliable admission requirement for non-Science university studies. Finally the paper provides a strong motivation for a name change for this subject in South Africa.

Keywords: Mathematical Literacy, Quantitative Literacy, Numeracy, Quantitative skills, contextual mathematics, Umalusi curriculum research

INTRODUCTION

*What's in a name? That which we call a rose by any other name would smell as sweet.
(Shakespeare, 1600. Romeo and Juliet).*

¹ Date of submission 10 February 2015

Date of acceptance 3 June 2015

Mathematical Literacy is a school subject taught in Grades 10 – 12 at secondary school level in all South African schools. It is a compulsory subject choice for all learners who do not do Mathematics at Grade 12. In South Africa, (and England since 2010), the subject is taught at secondary school level; in the United States it is taught at university and colleges, in some instances to provide access to advanced Mathematics courses. There is a common perception among most South Africans that Mathematical Literacy is 'maths for dumb kids' or 'just like standard grade maths' or 'that it's a basic function (like reading and writing which was done in Grade 1)'. Concerned parents do not want their children to 'drop down' to Mathematical Literacy. Some say 'it's Maths for those who can't do Maths' (Hamsa and Graven, 2006: 26). There is also a commonly held view among those in Higher Education that Mathematical Literacy is not a useful matric subject to offer for admission to higher education. Those who take Mathematics are considered to possess high mental prowess, be capable of abstract thinking and be able to solve complex problems. In contrast those who take Mathematical Literacy are thought to be capable of merely low-level, arithmetical thinking and computational skills.

One of the purposes of this paper is to refute these assertions and to provide factual evidence for why these perceptions and views are ill-founded. In the opinion of the Umalusi research team the perceptions described above are largely based on ignorance of the actual nature of Mathematical Literacy, the inadequate naming of the subject and a lack of understanding of how Mathematical Literacy has filled the vacuum left by educational changes and perspectives in South Africa since the 19th century in a radical way.

RESEARCH METHODOLOGY

In 2014, Umalusi (Council for Quality Assurance in General and Further Education and Training) proposed a research question into Mathematical Literacy to determine whether the content and skills in Mathematical Literacy compare with the problem-solving skills deemed necessary to be quantitatively literate by world standards. The team of researchers transformed this question into three questions.

1. What is Quantitative Literacy? What are its main characteristics (i.e. knowledge, skills and attitudes)?
2. Does Mathematical Literacy cover the skills considered necessary to be quantitatively literate by world standards?
3. To what extent does the Curriculum and Assessment Policy Statement (CAPS) for Mathematical Literacy encompass the skills and knowledge required for arithmetical / mathematical / quantitative problem-solving with respect to content, depth and breadth?

The research methodology included both quantitative and qualitative methods. The Umalusi research team, representing the teaching practice, curriculum and field experts as well as representation from higher education institutions, researched the history of education in South Africa since the 19th century, education acts and the types of quantitative knowledge and skills which are required for people to function optimally in the home, the workplace and in society in the 21st century. The literature survey included books, conference proceedings, papers, websites, current research and theses. The time given by Umalusi did not permit the authors to extend their research to survey the opinions of Mathematical Literacy teachers and learners, who, of course, constitute a very important sector with respect to the questions above. This would be a very significant and rich study for further research and might add fuel to the argument for higher education leaders to review their policies regarding Mathematical Literacy as a subject for admission.

BACKGROUND TO THE REASON FOR THE INTRODUCTION OF MATHEMATICAL LITERACY IN SOUTH AFRICA

Education in South Africa in the 19th and 20th centuries

In the period from 1800 to 1953 education for black children consisted basically of missionary education (Van der Walt, 1992). Much has been written about both the positive aspects of the missionary endeavour as well as some negative impacts. Suffice to say, many key leaders in South Africa attribute their educational beginnings to the efforts of mission-based teachers. Notwithstanding the colonial context of this education the outcomes were, in many cases, pivotal for the children concerned and for the history of the country.

The Bantu Education Act of 1953

When the National Party won the elections in 1948, racial segregation of black education was formalised and culminated in the passing of the Bantu Education Act of 1953. This Act, based largely on the recommendations of the Eiselen Commission (Ramoketsi, 2008), was to become the National Party's blueprint for education of black children. Armed with the Bantu Education Act of 1953, the government stated categorically that the education provided by missionaries could not be relied upon to root black people within their own 'tribal community' and that it had to be State-controlled in order to do so, as recommended by the Eiselen Commission.

Obviously, there was opposition to the implementation of Bantu Education which resulted in the demise of the work done by mission schools in providing education to black children, and this opposition came very strongly from black people themselves, and in particular from political organisations (e.g. the ANC and the White Liberal Party), from national community organisations (e.g. the Black Sash organised by women) and from other White South Africans. The national authorities of the time are often said to have viewed education as having a pivotal position in their goal of eventually separating (white) South Africa from the Bantustans. With specific reference to black learners, education in general and Mathematics learning and teaching, Dr Hendrik Verwoerd, in a speech delivered on 17 September 1953 on the Second Reading of the Bantu Education Bill, stated:

When I have control over native education I will reform it so that the Natives will be taught from childhood to realize that equality with Europeans is not for them. People who believe in equality are not desirable teachers for Natives... There is no place for [the Bantu] in the European community above the level of certain forms of labour ... What is the use of teaching the Bantu child mathematics when it cannot use it in practice? (Clark & Worger, 2004).

Verwoerd's policies of discrimination meant that blacks learners were discouraged from taking Mathematics as one of the subjects at school as noted above when he said 'What is the use of teaching the Bantu child mathematics when it cannot use it in practice?' Hence, many black learners could not take Mathematics as a subject through to the end of their secondary/high school studies since many schools did not anyway offer Mathematics at the senior secondary level. For instance, according to a report commissioned by the Department of Education and Training and the Department of Arts, Science and Technology, by 1997 KwaZulu-Natal still had 156 high schools that did not offer Mathematics at the Grade 12 level (Arnott, Kubeka, Rice & Hall, 1997).

Most teacher training during the apartheid years took place at segregated and apartheid-constructed teacher training institutions, the so-called 'Colleges of Education', and many black teachers in South Africa received training at these colleges where they could either take a two-year certificate course, or a three-year diploma course. The Primary Teachers Certificate (PTC) was a two-year certificate course that enabled teachers to teach at a primary school and the Junior Secondary Teachers Certificate (JSTC) enabled teachers to teach up to Junior Secondary schools.

From the 1980s, the Colleges of Education, which had proliferated in numbers in the homelands and self-governing states (Chisholm, 2009), started offering an improved curriculum, compared to the two-year certificate courses, and it consisted of a three-year Primary Teachers Diploma and/or Secondary Teachers Diploma. Nevertheless, the curricula in these diploma courses still did not reach the required standards and provide quality education as expected by many scholars and educators (Arnott et al., 1997). For instance, teachers who were trained to teach Mathematics at senior secondary level did not do any Mathematics beyond Grade 12. In other words, the mathematical knowledge that the Mathematics teachers would obtain after spending three years at a College of Education would be the same as the learners they would be teaching at high schools. They did not have the benefit of having more mathematical knowledge than their learners which would have enabled them to have greater confidence, insight and understanding of the subject they would be teaching at Grades 10-12. Furthermore they had minimal opportunities to strengthen their subject knowledge base for teaching. Arnott et al. (1997) actually reported, in their 1997 audit of Mathematics and Science teacher education that over 50% of the secondary level Mathematics teachers at that time had less than one year of post-secondary study in the subject. Due to the challenges that black Mathematics teachers encountered, including the inadequate training, the quality and standard of teaching and learning of Mathematics in black schools was called into question. What this has translated into is the fact that Bantu Education has led to the current poor performance in Mathematics of South African learners today. Kahn (2001) observes that the pass rate for Grade 12 black learners in Mathematics in 1999, 2000, 2001 and 2002 was 17.7%, 15.6%, 20% and 23.2% respectively. This situation has had a cascading effect since poorly qualified teachers produced low achieving mathematics matriculants, who also then, if they choose to take teaching as a profession, become poorly qualified mathematics teachers.

The South African Schools Act, no. 84 of 1996

The South African Schools Act, no. 84 of 1996, sought to ensure a uniform system in schools. One of the main objectives of the Act was to amend and repeal certain laws relating to schools and to provide for related matters. The Act recognised that a new national system for schools needed to redress past injustices, and to support the rights of learners, educators and parents. It also set out the duties and responsibilities of the State. Under apartheid South Africa, there were 19 education departments, and eight of these used different curricula and offered different standards of learning quality. These included nation-wide departments for coloured learners, Indian learners, black learners, a department for independent schools, and provincial departments for white learners in each of the former four provinces. Some of the homelands and self-governing territories that were incorporated back into South Africa in 1994 also had their own education departments, but the curricula used and followed were from the nation-wide department for black learners.

According to Msila (2007) it is partly the history of South African education that necessitated the introduction of Curriculum 2005 from January 1998. It was clear that the previous education system had fallen short of international standards. In addition, the transition and transformation from apartheid education to a new South African education system needed to be rooted within the fundamental values enshrined in the democratic Constitution; values such as, democracy, social justice, non-racism, non-sexism, equality and reconciliation were seen as very important in the newly founded South African democracy. Consequently, the Outcomes Based-Education (OBE) system basically introduced new learning styles where, for example, there was change from passive, rote learning to creative learning and problem solving through learners' active participation in the learning process. However, the introduction and implementation of OBE was made more difficult by the fact that many teachers were not part of the formulation of the curriculum process (Jansen, 1997).

Subsequently, Curriculum 2005 and its implementation were reviewed by a Ministerial Committee in 2000, and the Revised National Curriculum Statement was formulated which was 'not to be seen as a new

curriculum but a streamlining and strengthening of Curriculum 2005' (Department of Education, 2002: 6). According to the Department of Education, the Revised National Curriculum Statement would keep intact the principles, purposes and thrust of Curriculum 2005 and still affirmed the commitment to outcomes-based education. When the Revised National Curriculum Statement Grades R-9 (Schools) became policy, it would replace Curriculum 2005, and its introduction in the Foundation Phase was planned for 2004.

The introduction of Mathematical Literacy

To complete the cycle of the introduction of a new curriculum, the National Curriculum Statement for Grades 10-12 was to be implemented and introduced in Grade 10 in 2006, Grade 11 in 2007 and Grade 12 in 2008. The National Curriculum Statement at the time required all learners in Grades 10-12 to do seven subjects. In fact, to be awarded the National Senior Certificate, learners had to complete seven (7) subjects and also meet stated minimum requirements. The subjects were specified as follows: two (2) South African languages, Mathematics or Mathematical Literacy, Life Orientation, and three (3) choice subjects. In other words, the National Curriculum Statement (Grade 10-12) came with a requirement that all learners had to do either Mathematics or Mathematical Literacy.

The big question was:

Why introduce a new subject, namely, Mathematical Literacy, and what was the purpose?

According to the Department of Education, Mathematical Literacy is defined as a subject that

provides learners with an awareness and understanding of the role that mathematics plays in the modern world. Mathematical Literacy is a subject driven by life-related applications of mathematics. It enables learners to develop the ability and confidence to think numerically and spatially in order to interpret and critically analyse everyday situations and to solve problems (Department of Education, 2003: 9).

The Department of Education (2003) argued that South Africa has come from a past in which poor quality education or lack of education has resulted in very low levels of literacy and numeracy in our adult population. International studies have shown that South African learners fare very poorly in mathematical competence tests when compared to their counterparts in other developed and developing countries. In the Trends in International Mathematics and Science Study (TIMSS) which is a series of international assessments of the mathematics and science knowledge of students around the world, South Africa scored the lowest for mathematics in 1995 (out of 41 countries), in 1999 (out of 48 countries) and in 2003 (out of 45 countries). (The TIMSS results for 2011 show a significant improvement from the previous very low scores of South African learners. However, their ranked position has not altered in comparison to the other countries tested.) Prior to the introduction of Mathematical Literacy, learners who did not achieve a pass mark in Mathematics in the General Education and Training Phase usually dropped Mathematics at the end of Grade 9, thus contributing to a perpetuation of high levels of innumeracy.

The inclusion of Mathematical Literacy as a fundamental subject in the Further Education and Training curriculum is to ensure that our citizens of the future are highly numerate users of mathematics. In the teaching and learning of Mathematical Literacy, the intention is to provide learners with opportunities to engage with real-life problems in different contexts, and so to consolidate and extend basic mathematical skills. Thus, Mathematical Literacy, properly taught, will result in the ability to understand mathematical terminology and to make sense of numerical and spatial information communicated in tables, graphs, diagrams and texts. Furthermore, Mathematical Literacy intentionally develops the use of basic mathematical skills in critically analysing situations and creatively solving everyday problems.

Before the National Curriculum Statement was introduced, learners could choose to take Mathematics on Higher Grade level, Standard Grade level or not at all. The 'not at all' part is the dismaying statistic.

Brombacher (2010), who was an adviser and consultant for the Minister of Education with regard to the compulsory requirement for learners in Grades 10-12 to take either Mathematics or Mathematical Literacy, revealed some interesting statistics. These statistics could have swayed the Ministry's decisions on the matter: he noted that as many as 40% of learners were not taking any Mathematics at all each year during the period 2000-2005. Furthermore, about half the learners who took Mathematics were taking it on the Standard Grade level. Over the same period 2000-2005, the average percentage of learners out of the entire cohort of the Matriculation examination candidates who got a mere pass in Higher Grade Mathematics was a mere 5.2%.

Mathematical Literacy was introduced in schools in the FET Phase (Grades 10-12, with learners mainly aged between 15 and 18) in South Africa during January 2006. According to Botha (2011), in 2006 South Africa was the only country in the world to offer Mathematical Literacy as a subject at school. According to Christiansen (2006), 200 000 more learners were given the opportunity in 2006 to interact with mathematics than in previous years when mathematics was not obligatory for all learners. Consequently, Christiansen (2006) asserts that Mathematical Literacy will offer greater access to mathematics for all learners and could offer a more accessible opportunity for learners to succeed in a mathematical subject. The implementation of this mandatory subject has resulted in renewed national interest in mathematics transformation in South Africa, challenging the mathematics educational experts to look more deeply into the purposes, principles and scope of this transformation in order to ensure its successful implementation. Policy makers and interested parties in certain quarters even went as far as suggesting that Mathematical Literacy should be offered as one of the mandatory subjects instead of a choice subject as it prepared learners for real-life situations.

THE MAIN CHARACTERISTICS OF 'QUANTITATIVE LITERACY'

The survey of literature resulted in a compilation of 32 definitions of a subject which is variously called Mathematical Literacy (mainly in South Africa), Quantitative Literacy (mainly in the USA and Hong Kong), Quantitative Reasoning (mainly in the USA), Numeracy (worldwide) or Functional Mathematics (England). (For the purposes of this paper and for ease of comparison with Mathematical Literacy the four last-named subjects, as a group, will be called 'Quantitative Literacy' in the rest of this paper. However, when the context requires that all four be named they will be listed separately.) The analysis of definitions involved looking for common or very similar words and common or very similar ideas. It also involved considering the meaning of the definition as a whole. A list of the quantitative skills in Quantitative Literacy, Quantitative Reasoning, Numeracy and Functional Mathematics was identified and grouped into five subsets:

- computational skills
- application of mathematical content
- reasoning skills
- statistical analysis and application skills
- communication skills.

These skills were then compared in great detail to the skills described in the *Curriculum and Assessment Policy Statement for Mathematical Literacy*. See Annexure 1.

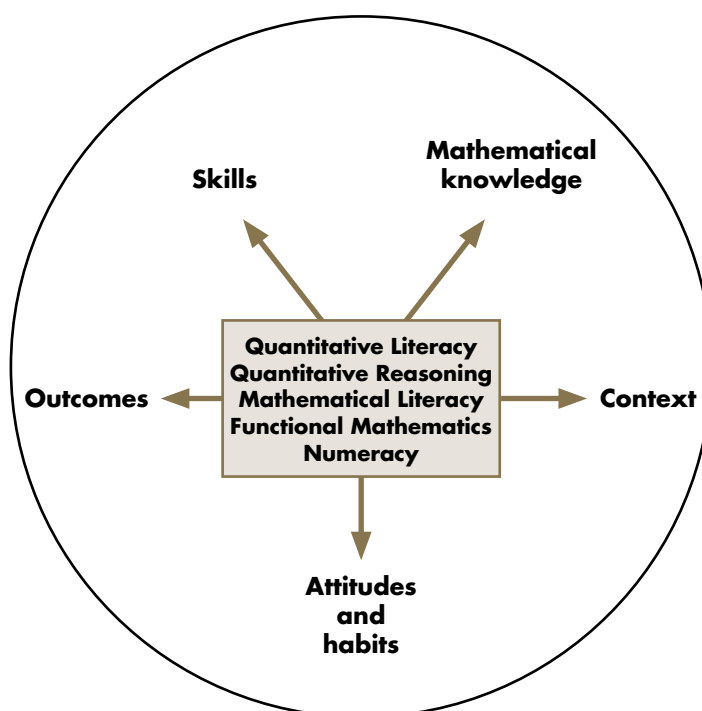
Another outcome of the survey was a comparison of the mathematical knowledge/content in Quantitative Literacy, Quantitative Reasoning, Numeracy and Functional Mathematics and the mathematical knowledge/content in the *Curriculum and Assessment Policy Statement (CAPS) for Mathematical Literacy* in South Africa. The full list of this content can be found in Annexure 2.

The layered analysis of the definitions was necessary to determine the relative depth and breadth of the South African curriculum to other curricula, where available and appropriate, and the broad sweep of skills considered necessary for high levels of quantitative functioning. The research team intended to ascertain whether the CAPS for Mathematical Literacy covers the same breadth and depth of mathematical content and the same general set of skills as the international cluster of subjects which purport to enable learners to become quantitatively literate and to be problem-solvers of real life quantitative problems. As mentioned above, the various definitions of Mathematical Literacy and the four international subjects were analysed with respect to skills, mathematical knowledge, attitudes and values, desired outcomes and contexts. The analysis and overall comparison revealed a very large commonality in these areas, namely,

- All are based on the same broad range of mathematical concepts (numeric, graphical, spatial, finance, statistics and probability).
- All require a set of computational skills, a set of mathematical content skills, a set of reasoning skills, a set of statistical analysis skills and a set of communication skills.
- The outcomes are all largely clustered around the improvement of the civic-mindedness and ability of people to cope with the demands of modern society.
- All are context-based and use authentic everyday situations in which to locate problem solving.

In analysing the *definitions* both the *words* chosen to define the subject and the *meaning* conveyed by the overall definition was considered. In the *definitions* found in the literature of these five subjects both knowledge and skills were grouped into subsets that are linked or related or similar in meaning for the purposes of comparison. For instance 'logical deduction' is considered to be an equivalent or very similar skill to 'reasoning'. The following list of the components of the definitions (as shown in Figure 1 below) is based on this grouping of related elements.

Figure 1:
Common features, characteristics and outcomes of Mathematical Literacy, Quantitative Literacy,
Quantitative Reasoning, Numeracy and Functional Mathematics



Mathematical Knowledge

- Broad range of basic mathematical concepts (number, ratio, percentage, linear growth, area, volume, etc.)
- Application or engagement with mathematical knowledge, principles and concepts in order to solve problems
- Logic, deduction and reasoning
- Use of real data and uncertain procedures in real-life situations

Skills

- Apply arithmetic operations; process, respond and think about mathematical information (numeric, quantitative, spatial, statistical); use mathematical tools as well as ICT in sophisticated settings
- Estimate values; identify errors; validate assertions
- Solve problems
- Probe given information; analyse and interpret
- Make well-founded judgements and draw conclusions
- Predict; conjecture; model situations mentally and formally
- Communicate - visually, verbally, orally
- Understand and make sense of or engage with context; use appropriate skills in different contexts
- Control or manage situations

Outcomes

- Become concerned, reflective, participating, self-managing, contributing citizens
- Cope with quantitative demands of modern society
- Fundamental component of all learning-performance, discourse and critique

Attitudes and values

- Habits of mind
- Beliefs and dispositions
- Confidence in quantitative situations

Context

- Life-related applications in a variety of contexts, personal, familiar, societal, work-based, unfamiliar

Based on the *definitions* alone, it is quite clearly seen that the content, skills-set and purpose of Mathematical Literacy are almost identical to 'Quantitative Literacy'. There are different emphases in some of the subjects, some of which are linked to the historical origin of the subject. For example Functional Mathematics, which was introduced in all secondary schools for all learners up to GCSE in England in 2010, emphasises the inter-disciplinary nature of being quantitatively functional and it is taught alongside Mathematics (Hamsa and Graven, 2005). Quantitative Literacy, in the USA, is seen in some institutions as a gateway to advanced mathematics courses. (Dossey, 1997). Numeracy includes the need for ICT skills as well as other quantitative skills.

Apart from this in-depth analysis, examination of a selection of actual definitions shows the common characteristics and purpose that the five subjects share:

People who are **quantitatively literate** are able to think and reason across the various aspects of mathematical behaviours, actively use concepts, principles, and skills to make sense out of situations they encounter. This requires that they integrate not only content but also the cognitive processes required to probe, interpret, conjecture, validate and communicate what the various aspects of mathematics reveal about a given situation. The ability to use mathematics as a tool to make sense of situations in the environment requires that people model the situations (mentally or formally), bring to bear their mathematical knowledge and work towards a solution (Dossey, 1997).

Numeracy is 'the ability to process, interpret and communicate numerical, quantitative, spatial, statistical, even mathematical information in ways that are appropriate for a variety of contexts, and that will enable a typical member of the culture to participate effectively in activities they value' (Evans, 2000: 236).

If literacy is the ability to read and write, then **Mathematical Literacy** should be the ability to read, write, and engage with information and situations that are numerical in nature and mathematical in structure. While the mathematically literate person may draw on mathematical algorithms or knowledge, their mathematical literacy is reflected in habits and behaviours and ways of engaging with problems and situations (AMESA, 2003: 2).

In defining **Quantitative Reasoning** a continuum is a useful metaphor, cruder than many and certainly not the only approach to defining quantitative reasoning. But it does provide a useful sense of direction while we think about the effect of computers on the past and future of quantitative reasoning. The Low end: calculating in a fixed and familiar context. The Middle: solving problems in a particular applied context. The High end: reasoning about relationships (Cobb, 1997).

Functional Mathematics in England is currently defined thus:

- Each individual has sufficient understanding of a range of mathematical concepts and is able to know how and when to use them. For example, they will have the confidence and capability to use maths to solve problems embedded in increasingly complex settings and to use a range of tools, including ICT as appropriate.
- In life and work, each individual will develop the analytical and reasoning skills to draw conclusions, justify how they are reached and identify errors or inconsistencies. They will also be able to validate and interpret results, to judge the limits of their validity and use them effectively.

Finally, 'whatever the terms used (*for this subject*) "an emerging concern is with linking knowledge, skills, attitudes and values produced through mathematical literacy to those needed for effective participation in democratic life in the 21st century"' (Vithal, 2006: 37).

From this analysis of definitions the research team asserts that the subject called Mathematical Literacy (in South Africa) is virtually the same subject as taught in other countries under another name. The differences are small and mainly in emphasis.

DOES THE CAPS FOR MATHEMATICAL LITERACY TEACH SKILLS WHICH ENABLE SOUTH AFRICAN MATRICULANTS TO BE QUANTITATIVELY LITERATE BY INTERNATIONAL STANDARDS?

The Umalusi research team undertook a further examination of the similarities between Mathematical Literacy and 'Quantitative Literacy'. The first analysis looked beyond formal definitions to the descriptions

and specification of Quantitative Literacy, Quantitative Reasoning, Numeracy and Functional Mathematics. The next task was to identify the skills found in all these subjects. What follows is the full list of skills that are found in the literature of these subjects.

Table 1:
Skills in 'Quantitative Literacy'

1. Computational Skills

- Apply arithmetic operations, using numbers embedded in print material
- Calculator skills
- Check the reasonableness of calculated values
- Computational/Algorithmic skills
- Use new technologies / Use mathematical tools as well as ICT in sophisticated settings / Computer skills
- Estimate the right order of magnitude of the solution/ Estimation of numbers

2. Application of Mathematical Content

- Actively use concepts and principles
- Apply the mathematical content areas
- Apply elementary mathematical tools in sophisticated settings
- Apply technical knowledge
- Confidence to apply mathematical knowledge
- Life-related application of mathematics
- Problem-solving skills
- Understand multi-variate models
- Understand the impact of different rates of growth
- Use appropriate skills in different contexts / Grounded appreciation of the context

3. Reasoning

- Analyse evidence
- Analyse, synthesise and evaluate
- Confidence to think numerically and spatially
- Use critical thinking skills
- Draw conclusions
- Evaluate the decision that values lead to /Evaluate risks
- Formulate the problem / Develop and interpret models related to problems/Determine the best analytical approach
- Guess and check / Make conjectures
- Identify errors / Detect fallacies
- Integrate content and cognitive processes
- Interpret and critically analyse in order to solve problems
- Interpret the meaning of calculated values
- Judge independently
- Justify an assertion

- Make decisions / good judgements
- Make sense/engage with context
- Make or critique an argument
- Model situations mentally and formally
- Probe information
- Process, respond and think about numeric, quantitative, spatial, statistical, mathematical information
- Reason and think / Reason in numerical, data, spatial and chance settings
- See connections
- Think deductively or logically / Think mathematically and strategise
- Understand
- Validate

4. Statistical Analysis

- Ask the right questions about data
- Assess the quality of the information; assess claims
- Draw inference from data
- Engage meaningfully with personal, social and political issues
- Find information
- Interpret data
- Predict (using probability)
- Recognise the difference between correlation and causation
- Recognise the difference between randomised experiments and observational studies
- Reason statistically
- Understand, predict and control situations important to their lives
- Weigh evidence / Compare

5. Communication

- Use spreadsheets and create other graphic displays on computers
- Communicate findings visually, verbally, orally
- Communicate simple quantitative ideas in English
- Communicate what Mathematics reveals
- Construct, communicate and evaluate an argument
- Interpret, apply and communicate mathematical information
- Language, reading and comprehension / Read, write and engage with numerical information
- Represent answers in text or graphically
- Use written and graph source material
- Use verbal / Interpretive skills

From the list above it can be seen that this set of skills is broad and deep, cognitively demanding and complex, applicable to important problem-solving situations in which we live, very useful and highly relevant to life today. Steen (1997) compares the vulnerability of a quantitatively illiterate citizen in today's society to that of an illiterate peasant in Gutenberg's time, when the printing press was invented. He adds (2007) that democracy itself is in danger if most citizens are '*quantitatively oblivious*'.

The research revealed that the CAPS for Mathematical Literacy shares (with a few minor differences) the five main sets of skills described in the other four subjects. The skills are grouped into five main categories:

- Use basic **computational skills** in everyday contexts
- Apply known **mathematical content**
- **Reason** in order to draw and communicate conclusions
- **Statistically analyse** and represent information
- Use appropriate **communication skills** to participate effectively in the household, workplace or in wider social and political contexts.

The ability to use basic computational skills is evident throughout the CAPS and great attention is given to estimation skills and mathematical tools. The CAPS goes into depth and places emphasis on skills such as reasoning; analysis, interpretation, justification and making sense of real-life contexts as well as application of mathematical content problem-solving skills and life-related application of mathematics. An overarching element of the CAPS is the skill of communicating the answer either verbally or graphically or in some visual representation. The numerous detailed skills in CAPS were grouped to align with the five subsets listed in Table 1 above. The CAPS document is extremely well specified with respect to the skills required to achieve the objectives of Mathematical Literacy. From this survey and comparison it is clear that the skills of Mathematical Literacy correspond very closely with the skills recognised internationally as skills which quantitatively literate people have and use. The detailed comparison of the skills in CAPS and the literature review can be found in Annexure 1: Comparison of skills in the literature review of 'Quantitative Literacy' and skills in the Mathematical Literacy CAPS.

TO WHAT EXTENT DOES THE CURRICULUM AND ASSESSMENT POLICY STATEMENT (CAPS) FOR MATHEMATICAL LITERACY DESCRIBE IN BOTH DEPTH AND BREADTH THE SKILLS AND KNOWLEDGE REQUIRED FOR ARITHMETICAL / MATHEMATICAL / QUANTITATIVE PROBLEM SOLVING?

In order to find answers to this question, the research team compared the mathematical content areas described in the literature in Quantitative Literacy, Quantitative Reasoning, Numeracy and Functional Mathematics with the mathematical content areas described in the CAPS for Mathematical Literacy. The researchers also reflected on the depth and breadth of the specialisation of the skills required in Mathematical Literacy which deal with problem solving. (See Annexure 1.)

In the literature the main areas of problem solving in which people require quantitative skills are Numeric computation, Financial, Spatial (or visual), Statistical and Probability problems. Table 2 below shows how these general areas correspond with the structure and content of Mathematical Literacy.

Table 2:

A comparison of the problem-solving content areas in Mathematical Literacy and 'Quantitative Literacy'

CAPS	Literature review of 'Quantitative Literacy'
Interpreting and communicating answers and calculations	Arithmetic/numeric calculations, Proportional reasoning, e.g. in ratio problems Linear and exponential graphs, Pattern recognition, variables and relations, solving non-linear equations, Working with models of linear and exponential growth
Numbers and calculations with numbers	
Patterns, relationships and representations	

CAPS	Literature review of 'Quantitative Literacy'
Finance	Production rates and price schemes
Measurement	Area of rectangle and circle and volume of rectangular solids, spheres, cylinders and cones, measurement
Maps, plans and other representations	Space and visualisation
Data handling	Extrapolation and fitting lines or curves to data, recording data, statistical analysis (measures of central tendency and dispersion)
Probability	Probability, combinatorics, e.g. combinations and permutations, expressed in tree diagrams and useful in probability

When the detailed content is examined the CAPS for Mathematical Literacy demands slightly more of learners in the mathematical content of the Financial and Spatial topic areas. However, the mathematical content complexity in Mathematical Literacy in Probability and Data handling is not as deep as in some Quantitative Literacy courses in the USA (Ganter, 2006). It should be noted that, whereas the research team had access to the detailed and highly specified CAPS document for Mathematical Literacy, for most of the descriptions of the content areas of the other subjects we had to rely on condensed or bulleted summaries of the content. However, from the overall discussion of the other subjects it can be assumed that much of what is specified in the CAPS is implied in the other curricula.

Other shared problem-solving characteristics of Mathematical Literacy and 'Quantitative Literacy' are:

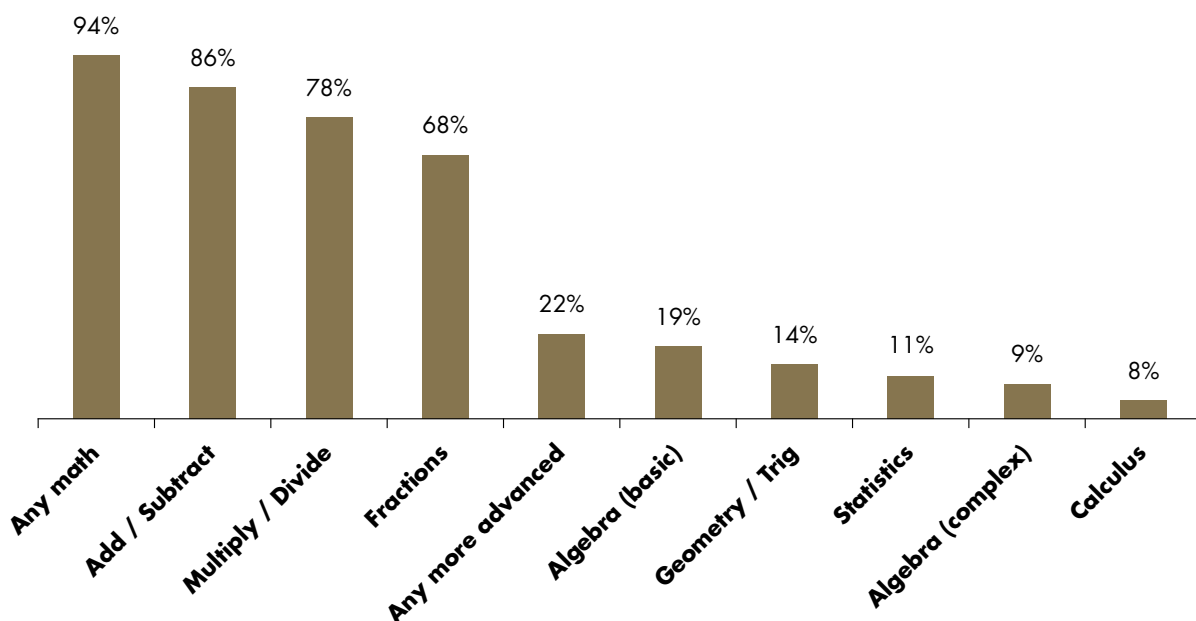
- the application of mathematical content in life-related contexts
- learners must be able to work with actual real-life problems and resources rather than with problems developed around contrived, semi-real and / or fictitious scenarios.
- reasoning and communication are referred in each context and at every level.
- confidence to interpret information, understand the problem, apply mathematical content and skills, reason and communicate, seem to be generally accepted skills.

In summary, it is reasonable to assert that Mathematical Literacy requires the same types and levels of problem-solving skills, using the same mathematical competencies, as 'Quantitative Literacy' ('Quantitative Literacy', Quantitative Reasoning, Functional Mathematics and Numeracy) in the international context.

WHAT IS THE DIFFERENCE BETWEEN MATHEMATICS AND MATHEMATICAL LITERACY?

While acknowledging that Mathematics as a subject is vitally important for those learners that go on to study in the Higher Education phase in the fields of Science, Engineering and Actuarial Studies, it would seem that in the world of work the level of mathematics used is not very high. This was asserted by an American researcher in 2004-2009 (Handel, 2010) whose survey of more than 2000 workers in the USA in 2004-2006 and 2007-2009 found that less than a quarter of them used any more complicated mathematics than basic fractions and percentages in their jobs. In Figure 2 below the phrase 'any more advanced' refers to Algebra and Calculus.

Figure 2:
What percentage of Americans actually use Math at work?



Data: Michael Handel, 'What Do People Do at Work? A Profile of U.S. Jobs from the Survey of Workplace Skills, Technology and Management Practices (STAMP)'

However, what sets Mathematical Literacy apart from Mathematics as a completely different subject is how that mathematics is used. Mathematical Literacy does contain mathematical concepts, principles and knowledge. Most of this mathematics is at about the Grade 9 level, like performing numerical operations, negative numbers, calculating percentages, using ratios, drawing simple graphs, substituting into equations, working with models of linear and exponential growth, calculating statistical measures of central tendency, probability, spatial concepts like measuring and comparing values, often with different units, calculating the area of a rectangle and circle and the volumes of rectangular solids. (This list is not comprehensive.) The reason for the mathematics in Mathematical Literacy is not to learn it for its own sake. It is so that learners can use the mathematics as a tool to solve much more difficult problems all of which are authentic, relevant and commonly experienced in the lives of people in this century in South Africa. These are quantitative situations found in the home, in the workplace or in society at large, both in urban and rural contexts. The following are some of the areas that require the skills of Mathematical Literacy in the world, and particularly in the new democracy that is South Africa today. While the complete list of contexts below are quoted from Steen (2001) it is significant that the same examples are to be found in the CAPS document as areas of application of mathematical problem solving in the curriculum in South Africa. While there are no actual rural examples or contexts in Steen's list which deal specifically with indigenous knowledge in South Africa, the authors contend that all people whether rural or urban need to understand the issues listed below in order to control their own lives more successfully and avoid exploitation by those in positions of power, both politically and financially.

(i) Citizenship

- Understanding how different voting procedures can influence the results of elections
- Analysing economic and demographic data to support or oppose policy proposals
- Appreciating common sources of bias in surveys such as poor wording of questions, volunteer response and socially desirable answers

- Understanding how small samples can accurately predict public opinion, how sampling errors can limit reliability, and how sampling bias can influence results (Steen, 2001: 10)

(ii) Culture

- Recognising the power (and danger) of numbers in shaping policy in contemporary society
- Understanding how assumptions influence the behaviour of mathematical models and how to use models to make decisions (Steen, 2001: 11)

(iii) Professions

- Journalists need a sophisticated understanding of quantitative issues (especially of risks, rates, samples, surveys, and the statistical evidence) to develop an informed and sceptical understanding of events in the news
- Lawyers rely on careful logic to build their cases and on subtle argument about probability to establish or refute 'reasonable doubt'
- Doctors need both understanding of statistical evidence and the ability to explain risks with sufficient clarity to ensure 'informed consent' from patients (Steen, 2001: 12)

(iv) Personal Finance

- Calculating income tax and understanding the tax implications of financial decisions
- Estimating the long-term costs of making lower monthly credit card payments
- Understanding the different factors affecting a mortgage
- Using the Internet to make decisions about travel plans (routes and reservations)
- Understanding that there are no schemes for winning lotteries
- Choosing insurance plans, retirement plans or finance plans for buying a car or house (Steen, 2001: 13)

(v) Personal Health

- Interpreting medical statistics and formulating relevant questions about different options for treatment in relation to known risks and the specifics of a person's condition
- Understanding medical dosages in relation to body weight, timing of medication and drug interactions
- Weighing costs, benefits and health risks of heavily advertised new drugs
- Understanding terms and conditions of different health insurance policies, verifying accuracy of accounts and payments
- Understanding the impact of outliers on summaries of medical data (Steen, 2001: 14)

(vi) Management

- Developing a business plan, including pricing, inventory, and staffing for a small retail business
- Determining the break-even point for manufacturing and sale of a new product
- Gathering and analysing data to improve profits
- Reviewing the budget of a small non-profit organization and understanding relevant trends
- Calculating the time differences and currency exchanges in different countries (Steen, 2001: 14)

It is essential that there be an understanding that Mathematics and Mathematical Literacy are different subjects altogether, not just different types or levels of mathematics. The table below illustrates this.

Table 3:
Differences between Mathematics and 'Quantitative Literacy'

Mathematics	Quantitative Literacy
Power in abstraction	Real, authentic contexts
Power in generality	Specific, particular applications
Some context dependency	Heavy context dependency
Society independent	Society dependent
Apolitical	Political
Methods and algorithms	Ad hoc methods
Well-defined problems	Ill-defined problems
Approximation	Estimation is critical
Heavily disciplinary	Interdisciplinary
Problem solutions	Problem descriptions
Few opportunities to practice outside the classroom	Many opportunities to practice outside the classroom
Predictable	Unpredictable

Bernard Madison's table (Calculation vs Context, 2008: 11)

The link between the mathematical knowledge learned in Mathematical Literacy and the everyday contexts in which the problems are to be found is the large number of skills that are learned by doing Mathematical Literacy. The skills outlined in Table 1 above demonstrate that the range of skills in Mathematical Literacy is very wide. There are also many demanding cognitive skills and extremely complex skills. And of great importance, there is a broad set of written, oral and graphical communication skills.

Based on an in-depth study of the skills and competencies of this subject, the research team is of the opinion that these skills are not only necessary and useful for the educated person in modern society but they are also skills which equip the high-achieving Mathematical Literacy learner to cope well with Higher Education in the non-STEM (Science, Technology, Engineering and Mathematical) fields.

IS MATHEMATICAL LITERACY IN NEED OF A 'MAKE-OVER'?

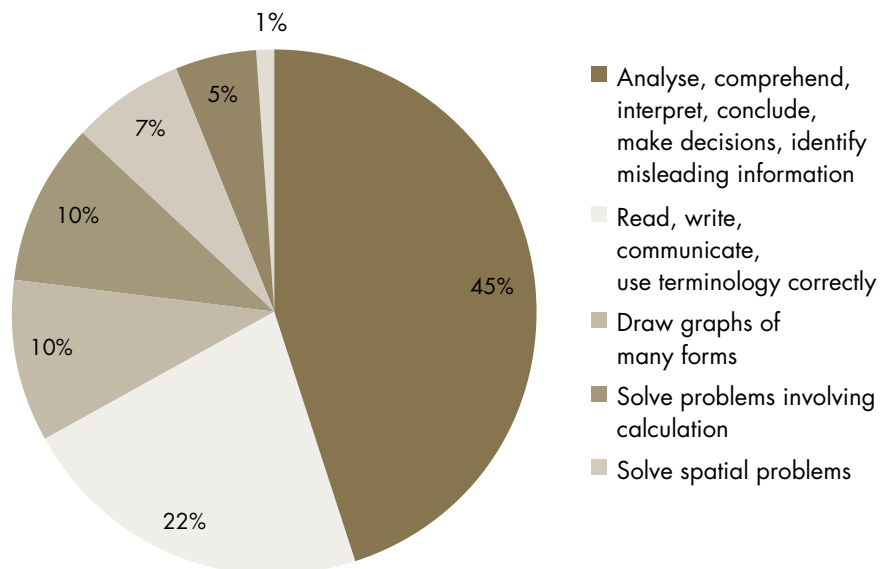
If the perception of Mathematical Literacy as second-class, poor relative of Mathematics is to be changed, then we need to consider a few important questions. The changed perception needs to be based on substance rather than ignorance or perception. It needs evidence and good reason rather than defensiveness.

(i) *Is there substance to the claim that Mathematical Literacy is cognitively demanding and can equip high-achievers for university studies?*

A recent study of the outcomes of Mathematical Literacy (based on an analysis of the CAPS document) shows that by far the largest proportion of skills required to perform well in this subject are of a high cognitive level. These are skills such as being able to interpret, analyse, draw conclusions, and make and justify decisions. Mathematical Literacy also requires a high level of communication, including reading,

writing and comprehension skills. The figure below shows the actual breakdown of exit-level skills for Mathematical Literacy.

Figure 3:
Exit-level skills for Mathematical Literacy



While acknowledging that the mathematical complexity and abstractness of Mathematical Literacy is not anywhere near the same level as mathematics, none-the-less the skills required to achieve a high performance in Mathematical Literacy are essential skills to perform well in higher education in the Humanities and Social Sciences.

(ii) *What is the value of this subject?*

Apart from having value as a valid admission offering for higher education, Mathematical Literacy has intrinsic value in and of itself. If taught as it should be, namely based upon authentic relevant contexts then every problem solved adds value to the life skills and ability of the learner to become an informed adult and 'to use mathematics effectively to meet the general demands of life at home, in paid work, and for participation in community and civic life' (AAMT, 1997: 15). 'Mathematical literacy is reflected in habits and behaviours and ways of engaging with problems and situations' (AMESA, 2003: 2). In South Africa how many waged people understand what their net salary really represents? How many South Africans who borrow money, especially from 'Loan Sharks', actually know what rate of interest is being charged and in what time period they will need to repay the interest? Ignorance of these simple quantitative issues often results in injustice and untold suffering. Being able to understand and manage one's financial situation, whether at the very low or high end of the financial spectrum is an empowering experience and a protection from exploitation.

Increasingly, the decisions which affect our lives are being taken at government level without our consent or input. Many major national issues rest on complex quantitative arguments such as rates of growth and economic forecasts. In some popular views expressed in the media it seems that every opinion is equally valid and that when there is disagreement in civic discourse, the truth lies somewhere in the middle (Kolata, 1997). Failure to grasp the complexity of quantitative issues may lead to an ever-widening gulf between those who are quantitatively literate and those who are not.

Mathematical Literacy is the subject poised to address citizens' potential ignorance of the quantitative issues that affect their lives. What they learn in this subject may be useful ten years after leaving school

when faced with one of the many real-life situations addressed in Mathematical Literacy. Doyen and champion of Quantitative Literacy in the USA, for more than two decades, Steen (2001) is convinced that the ability to see the world through mathematical eyes, and to approach complex problems with confidence in the value of careful reasoning is essential to equip 21st century people to ask intelligent questions of experts and to confront authority confidently.

(iii) Is SA a world leader in secondary education in the teaching of Quantitative Literacy?

For the reasons explained in the background to this paper, Mathematical Literacy was introduced into secondary education in 2006 at Grade 10 level. Since then Functional Mathematics (which is similar in content and skills with Mathematical Literacy) was introduced into high schools in England in 2010 from Year 8 -11 as a *compulsory additional* subject to Mathematics for all learners. In the USA courses in Quantitative Literacy have been offered at college and university level for more than a decade. These courses contain the same mathematical skills and content and application areas as Mathematical Literacy, although, in many cases at a more complex level, particularly if the Quantitative Literacy course is offered at three successive year levels at university. However, the question is now being raised amongst mathematics educators in the USA as to whether Quantitative Literacy should be introduced at secondary school level either across the disciplines or as part of Mathematics (Steen, 2007). The conversation in the USA continues. It is clear, however, that the need is felt at secondary school level for learners to become more quantitatively literate. Will time show that the South African education system perhaps unwittingly became a world leader by introducing a subject which is extremely relevant and increasingly necessary at secondary level before it was introduced in the rest of the world?

(iv) Who should do Mathematical Literacy?

From the arguments of this paper the reader should realise that doing mathematics does not make one quantitatively literate. Even Berkeley-educated mathematician and educator, Alan Schoenfeld (2001) called his mathematics education from grade school to PhD level 'impoverished: no authentic applications, no data other than artificial numbers, no communications other than formal proofs'. By virtue of the complete distinctiveness of Mathematical Literacy as a school subject, it would make sense to make it a subject that all could take, including those doing Mathematics. Its usefulness and value in later life is without question. In terms of educative value it teaches essential skills which are transferrable and applicable across the curricula. Such an approach would enhance the perception of Mathematical Literacy by learners and the public and result in more highly skilled Mathematics learners.

MAKING A CASE FOR A NAME CHANGE OF MATHEMATICAL LITERACY IN SOUTH AFRICA

The time has come to change the name of Mathematical Literacy. The word 'Mathematical' gives the perception that it is a kind of mathematics, i.e. dumbed down to a lower level or standard grade. The word 'Literacy' is interpreted by some to refer to what small children or uneducated adults do when they learn to read. Of course this is based on ignorance of the meaning of the word 'literacy' which means 'competence or capacity'. The writers of this paper favour the name Quantitative Literacy. It is increasingly used internationally and refers to quantitative skills, some of which are non-mathematics skills, but which rely upon sense-making, reasoning and mature decision-making. What a wonderful change from Maths-Lite!

CONCLUSION

The writers of this paper strongly argue that Mathematical Literacy is little understood across the public spectrum, and that it compares extremely well to international subjects taught at secondary level (in the UK) and tertiary level (in the USA). It teaches a set of vitally important skills and dispositions which are

valuable in themselves for making sense of the highly quantitative world we live in, as well as being good preparation for higher education in the non-Science fields. Finally, as well as providing an answer to the Umalusi Council research question, we hope that this paper will be used, in different formats and in different forums, to send out a strong signal to the educators at the basic and higher levels and to the South African general public that Mathematical Literacy is not a second-rate subject worthy of derision and scorn. It is rather, a relevant, cognitively challenging and necessary subject for an educational system that purports to equip young people for higher education and the challenges of life in the 21st century.

REFERENCES

Arnott, A., Kubeka, Z., Rice, M. & Hall, G. (Eds.) (1997) *Mathematics and Science teachers: demand, utilisation, supply, and training in South Africa*. Report for the Department of Education and Training and the Department of Arts, Culture, Science and Technology (2003). Cape Town: EduSource. Association of Mathematics Educators of South Africa (AMESA).

Australian Association of Mathematics Teachers. (AAMT). (1997).

Botha, J.J. (2011) *Exploring mathematical literacy: the relationship between teachers' knowledge and beliefs and their instructional practices*. University of Pretoria, South Africa.

Brombacher, A. (2010) National Science and Technology Forum (NSTF). Proceedings of Workshop on Science, Technology, Engineering and Mathematics (STEM) Education held at the Old Mutual-MTN Science Centre, Umhlanga Ridge, KwaZulu-Natal, South Africa.

Christiansen, I.M. (2006) 'Mathematical Literacy as a school subject: Failing the progressive vision?' *Pythagoras* 64 pp.6-13.

Cobb, G.W. (1997) 'Mere Literacy is Not Enough' In L.A. Steen (Ed.) *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. New York: The College Examination Board.

Clark, N.L. & Worger, W.H. (2004) 'South Africa - The Rise and Fall of Apartheid' *Seminar Studies in History*. Harlow, England, New York: Pearson Education Limited. pp.48-52.

Department of Education (2002) *Policy: Revised National Curriculum Statement Grades R-9 (Schools)*. Overview. Government of South Africa Press: Pretoria.

Department of Education (2003) *National Curriculum Statement Grades 10-12 (General)*. *Mathematical Literacy*. Government of South Africa Press: Pretoria.

Department of Education (2011) *National Curriculum Statement: Curriculum and Assessment Policy Statement (Further Education and Training Phase Grades 10-12)*. *Mathematical Literacy*. Government of South Africa Press: Pretoria.

Dossey, J.A. (1997) 'National Indicators of Quantitative Literacy' In L.A. Steen (Ed.) *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. New York: The College Examination Board.

Evans, J. (2000) *Adults' Mathematical Thinking and Emotions: A Study of Numerate Practices*. London: Routledge. (Cited in Coben, 2003: 10).

Ganter, S.L. (2006) 'Issues, Policies, and Activities in the Movement for Quantitative Literacy' In R. Gillman (Ed.) *Current Practices in Quantitative Literacy*. Washington: Mathematics Association of America.

Hamsa, V. and Graven, M. (2005) *Pythagoras QCA2*.

Handel, M.J. (2010) *What do people do at work? A Profile of U.S. Jobs from the Survey of Workplace Skills, Technology, and Management Practices (STAMP)*. North-eastern University, USA.

Howie, S.J. (2001) *Mathematics and Science Performance in Grade 8 in South Africa 1988-1999*. Human Sciences Research Council. South Africa.

Jansen, J. (1997) 'Why OBE will fail' Paper presented at a National Conference on outcomes-based education (OBE), University of Durban-Westville, South Africa.

Jansen, J. & Taylor, N. (2003) *Educational change in South Africa 1994-2003: Case studies in large-scale education reform*. Vol.II (1) Education Reform and Management Publication Series.

Kahn, M.J. (2001) 'Changing science and mathematics achievement: Reflection on policy and planning' *Perspectives in Education* 19(3) pp.169-176.

Kolata, G. (1997) 'Understanding the news' In L.A. Steen (Ed.) *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. New York: The College Examination Board.

Madison L.B. & Steen, L.A. (Eds.) (2008) *Calculation versus Context: Quantitative Literacy and its implications for Teacher Education*. Washington D.C.: Mathematical Association of America.

Mathematical Literacy in South Africa and Functional Mathematics in England: a consideration of overlaps and contrasts. SA ePublications

Msila, V. (2007) 'From Apartheid Education to the Revised National Curriculum Statement: Pedagogy for Identity Formation and Nation Building in South Africa' *Nordic Journal of African Studies* 16(2) pp.146-160.

Ramoketsi, M.S. (2008) The transformation of Black school education in South Africa, 1950-1994: A historical perspective. *Unpublished PhD Thesis*, University of the Free State: Bloemfontein.

Schoenfeld, A.H. (2001) 'Reflections on an Impoverished Education' In L.A. Steen (Ed.) *Mathematics and Democracy: The Case for Quantitative Literacy*. USA: National Council on Education and the Disciplines.

South African History Online. (2014) 'The 1976 Students' Revolt' <http://www.sahistory.org.za/topic/youth-and-national-liberation-struggle-1894-1994> (Accessed 24 May 2014).

Steen, L.A. (1997) *Why Numbers Count: Quantitative Literacy for Tomorrow's America*. New York: The College Examination Board.

Steen, L.A. (2001) *Mathematics and Democracy: The Case for Quantitative Literacy*. USA: National Council on Education and the Disciplines.

Van der Walt, J.I. (1992) 'The culturo-historical and personal circumstances of some 19th-century missionaries teaching in South Africa' *Koers* 57(1) pp.75-85.

Vithal, R. (2006) Developing Mathematical Literacy through project work: A teacher/teaching perspective. *Pythagoras* 64, December pp.37-44.

ANNEXURE 1: COMPARISON OF SKILLS IN THE LITERATURE REVIEW OF 'QUANTITATIVE LITERACY' (QUANTITATIVE LITERACY, QUANTITATIVE REASONING, FUNCTIONAL MATHEMATICS AND NUMERACY) AND SKILLS IN THE MATHEMATICAL LITERACY CAPS

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Skill 1: Computational operations		
Apply arithmetic operations, using numbers embedded in print material	Analyse, interpret and understand completed tax return forms	59
	Analyse a financial statement	52
	Investigate budgets and income-and-expenditure statements	53
	Using tables and/or spreadsheets to construct a model of a loan scenario	57
	Applying operations using a large number of financial documents, e.g. household bills, shopping documents, banking documents, budgets, payslips, quotations, invoices, receipts, claim forms, tax forms and loan documentation	49
Calculator skills	Know and use the different functions on a basic calculator	21
	Use calculator to determine financial values	
	Add, subtract, multiply and divide whole numbers and decimals both with and without using a calculator, converting percentages to decimals	29, 34
	Perform simple interest calculations manually (that is, without the use of a calculator)	121
	Performing operations using numbers and calculator skills	21
	Perform simple and compound interest calculations manually using a basic calculator, pen and paper, and/or spreadsheets	55
Check the reasonableness of calculated values	Check appropriateness of a solution	26
	Check the appropriateness of a solution by comparing it to the estimated solution	21
	Determine the most appropriate form of rounding and/or number of decimal places	30
	Modify solutions as required by the context of the problem, rework problems	26

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Computational/ Algorithmic	Use a range of techniques to determine missing and/or additional terms in a pattern, including when the formulae are provided for calculations	39
Use new technologies / Use Mathematical tools as well as ICT in sophisticated settings / Computer skills	Use science and technology effectively and critically showing responsibility towards the environment and the health of others	6
	Apply technology	8
	Operations using numbers and calculator skills	21
	Converting from percentages to decimals using a calculator	34
	Perform simple and compound interest calculations manually using a basic calculator, pen and paper, and/or spreadsheets	55
	Model loan and investment scenarios using a pen, paper, basic calculator and tables, spreadsheets, and/or available loan calculators	56
	Use tables and/or spreadsheets to construct a model of a loan scenario	57
Estimate the right order of magnitude of the solution	Recognise that the way in which data is classified, sorted and/or grouped will affect how data is organised, summarised and represented	83
Estimation	Estimate anticipated solutions	26, 29
	Estimate values in tables and on graphs	21
	Estimated travelling distance and time and travel costs	115
	Use a given scale to estimate the distance between the two locations	124
	Estimate values from given graphs	126
	Estimate the values of the dependent and independent variables	44
	Estimate the value of a currency in relation to other currencies	60
	Estimate lengths and/or measure lengths of objects accurately to complete tasks.	64

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Estimate quantities of materials needed	79
Use of spreadsheets and creating other graphic displays on computers	Using tables and/or spreadsheets to construct a model of a loan scenario	57
	Perform simple and compound interest calculations manually using a basic calculator, pen and paper, and/or spreadsheets	54
Skill 2: Application of mathematical content		
Actively use concepts and principles	Basic ratio concepts and ratio calculations	21
	Probability concepts	95
	Using measurement concepts	62
Apply the mathematical content areas	Investigate a variety of different types of graphs in order to present a message to the reader, without getting bogged down by formal mathematical procedures	37
Applying elementary tools in sophisticated settings	Using different tools and representations that can be used to represent events involving probability in a graphical/pictorial way	93
	Use formula to determine missing and/or additional terms in a pattern	39
	Use of formulae in perimeter, area and volume calculations	40
	Use elementary calculations in order to solve complex financial problems	57
Applying technical knowledge	Direct and inverse proportion, fixed, linear, compound growth	21, 22
	Work with variety of graphs found in newspapers, magazines and other resources	37
	Making sense of graphs that tell a story	22
Confidence to apply mathematical knowledge	Mathematically literate students should have the capacity and confidence to interpret any real-life context that they encounter	9
	Confidence in solving problems	12
	Perform any calculation involving number concepts with confidence	27
Life-related application of mathematics	Learners must be exposed to both mathematical content and real-life contexts to develop these competencies	8
	The focus in Mathematical Literacy is on making sense of real-life contexts and scenarios	8
	Mathematical Literacy involves real-life contexts	8

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Learners must be able to work with actual real-life problems and resources, rather than with problems developed around constructed, semi-real and/or fictitious scenarios	8
	Alongside using mathematical knowledge and skills to explore and solve problems related to authentic real-life contexts, learners should also be expected to draw on non-mathematical skills and considerations in making sense of those contexts	9
	The purpose of this subject is to equip learners with the necessary knowledge and skills to be able to solve problems in any context that they may encounter in daily life and in the workplace, irrespective of whether the context is specifically relevant to their lives or whether the context is familiar	9
	Demonstrate both competence in mathematical content and the ability to use a variety of both mathematical and non-mathematical techniques and/or considerations to make sense of real-life, everyday, meaningful problems	96
	Develop the ability to use a variety of mathematical and non-mathematical techniques and/or considerations to explore and understand both familiar and unfamiliar real-life contexts	11
	Making sense of real-life contexts and scenarios, in the Mathematical Literacy classroom mathematical content should not be taught in the absence of context	10
	Learners who are mathematically literate should have the capacity and confidence to interpret any real-life context	9
	The solving of real-life problems commonly involves the use of content and/or skills drawn from a range of topics, and so, being able to solve problems based in real-life contexts requires the ability to identify and use a wide variety of techniques and skills integrated from across a range of content topics	9

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	The confidence with which learners are able to identify and utilise appropriate mathematical content, techniques and other non-mathematical considerations in order to explore authentic real-life contexts without guidance and/or scaffolding	12
	Contexts related to scenarios involving daily life, workplace and business environments, and wider social, national and global issues that learners are expected to make sense of, and the content and skills needed to make sense of those contexts	14
	Choose two different authentic real-life scenarios involving direct proportion and inverse proportion	32
	Identify and represent a relationship in daily life	43
	Additional contexts and/or resources include any other plans in the context of the learner's daily life and in less familiar contexts relating to simple and complex structures	78
	Use authentic real-life contexts and real-life data	96
Problem-solving skills	Compare solutions to a problem expressed in different units and make a decision about what unit is the most appropriate or useful for the particular context in which the problem is posed	123
	Investigate situations in which summarised and/or represented data is interpreted in different ways	87
	Build a model and use the model in conjunction with other content, skills or applications to solve a problem	125
	Identify and solve problems and make decisions using critical and creative thinking	6
	Ability to reason, make decisions, solve problems, manage resources, interpret information, schedule events and use and apply technology	8
	Using mathematical knowledge and skills to explore and solve problems related to authentic real-life contexts	9

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	To be able to solve problems in any context that they may encounter in daily life and in the workplace, irrespective of whether the context is specifically relevant to their lives or whether the context is familiar	9
	Apply appropriate mathematical and non-mathematical techniques needed to solve problems	11
	Solve problems in scenarios involving Finance, Measurement, Maps, plans and other representations of the physical world, Data handling and Probability	21
Understanding multi-variate models	Understanding that tables, graphs and equations can all describe the same relationship, but in different ways	43
Understanding the impact of different rates of growth	Comparing rates	33
	Analyse graphs showing changes in the inflation rate over time	58
	Compare differences in the rates of change between the dependent and independent variables for each of the relationships	45
	Investigate the advantages and disadvantages of the different types of accounts regarding access to money, bank charges and interest rates	55
	Realising that inflation represents the average increase in the prices of a variety of goods and services over time and that different items can have different inflation rates	58
	Compare the rates of increase/decrease in prices through calculation	58
	Comparing rates	33
Use appropriate skills in different contexts / Grounded appreciation of the context	Represent simple interest growth scenarios using linear graphs and compound interest growth scenarios using graphs showing compound change	55
	Mathematical Literacy develops a general set of skills needed to deal with a particular range of problems	9
	Draw on non-mathematical skills and considerations in making sense of different contexts	8
	To identify and use a wide variety of techniques and skills integrated from across a range of content topics	10

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Making sense of scenarios involving daily life, workplace and business environments and wider social, national and global issues and the content and skills needed to make sense of those contexts	13
Skill 3: Reasoning		
Analyse	Collect, analyse, organise and critically evaluate information	5
	Analyse graphs showing changes in the inflation rate over time	58
	Analyse a household bill, statement, income-and-expenditure statement	52
	Analyse the layout of the structure shown on the plan	77
Analysis of evidence	Analyse, interpret and understand completed tax return forms	59
	Analyse aspects of the layout and/or design of a structure	78
	Analyse the growth pattern of a baby/toddler	85
	Analyse data presented in graphs	85
	Analyse calculated and/or given measures of central tendency and/or spread	84
Analysis, synthesis and evaluation	Analyse problems and devise ways to work mathematically in solving such problems	8
	Analysing conclusions in terms of each stage of the statistical cycle to determine the reliability and validity of the conclusions	88
	Analysing graphs to determine trends or meaning in the data	88
	Interpret and analyse representations	43
Confidence to think numerically and spatially	Confidence in solving problems	12
	Perform any calculation involving number concepts with confidence	27
Critical thinking skills	Identify and solve problems and make decisions using critical and creative thinking	5
Draw conclusions	Conclusions should be analysed in terms of each stage of the statistical cycle to determine the reliability and validity of the conclusions	88
	Decide which average is the most representative of the majority of the data values	84

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Decide on the most appropriate procedure or method to find the solution to the question or to complete a task, and they may have to perform one or more preliminary calculations or complete one or more preliminary tasks before determining a solution	114
	Decide which method will be the most appropriate to compare the costs involved in the contracts	116
	Decide on the most appropriate representation for a given scenario	43
Evaluate the decision that those values lead to	Decide which average is the most representative of the majority of the data values	64
Evaluating risks	Use and work with situations involving probability in risk assessments	93
	Determining risk in applications for car, household and life insurance	95
	Analyse a table showing risk assessment profiles for people from different age groups and explain why particular age groups are classified as higher risks than others	127
Formulate the problem / Develop and interpret models related to problems they encounter / Determine the best analytical approach	Make decisions regarding appropriate stopping points during a journey based on considerations of fatigue, petrol consumption, travelling time, etc.	124
Guess and check / Conjecture	Check the appropriateness of a solution by comparing it to the estimated solution	21
Identify errors / Detecting fallacies	Ask questions about the way in which data has been collected, organised, summarised and represented to reveal possible sources of error/bias/misinterpretation	87
Integrate content and cognitive processes	Patterns, relationships and representations will be integrated throughout all topics	96

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Solve problems and explore contexts relating to the topics of Finance, Measurement, Maps, plans and other representations of the physical world, Data handling and Probability, and their ability to use number concepts and equations, tables and graphs in an integrated way in order to make sense of those contexts	97
	Content and/or skills are integrated across a variety of topics throughout teaching and learning, and in the assessment activities	99
	Use of integrated content and skills drawn from different topics	98
Interpret and critically analyse in order to solve problems	Investigate and describe a variety of different types of graphs in order to develop a feel for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
	Analyse a newspaper article describing proposed increases in electricity tariffs and make deductions about the implications of these increases for consumers	120
	Analyse graphs showing changes in income tax over different time periods and explain differences	122
	Analyse a budget for a household or business and make recommendation as to how the expenditure should be changed to improve the finances of the household/business	120
	Analyse a model and critique the layout of the structure shown in the model	125
Interpret the meaning of calculated values	Recognise and describe the meaning of different points on the graph	37
	Explain the meaning of these values in relation to the context in which the problem is posed	45
	Relevance/meaning of the break-even values	53
	The meaning of these measures in relation to the data should be determined	93
	Explain the meaning of a given scale	124
	Graphs should be analysed to determine trends or meaning in the data	88

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Judge independently	Justify comparisons and opinions with calculations or with information provided in the context	26
	Analyse a model and critique the layout of the structure shown in the model	125
	Make suggestions for alterations	78
	Critique a proposed travel route in relation to distance, estimated travelling times, etc, and suggest and justify possible alternative routes	124
Justify	Justify comparisons and opinions with calculations or with information provided in the context	26
	Identify and solve problems and make decisions using critical and creative thinking	5
	Use knowledge of inflation rates to argue and justify a particular salary increase	121
	Critique a proposed travel route in relation to distance, estimated travelling times, etc, and suggest and justify possible alternative routes	124
	Justify comparisons and opinions with calculations or with information provided in the context	21
	Justify comparisons and opinions with calculations or with information provided in the context.	26
Make decisions / good judgements	Interpret a measured value and make a decision based on the value	123
	Analysing these graphs will make it possible to decide which contract is the better option for a certain number of minutes of talk time during a month	42
	Identify and solve problems and make decisions using critical and creative thinking	5
	Decide on the most appropriate representation for a given scenario and then construct, interpret and analyse that representation	43
	Decide on an appropriate selling price for an item and/or service based on an expected percentage profit	53

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Decide which bank would be the better option for a particular customer	55
	Decide on where to position a house or a garden in relation to the position of the sun at different times of the day	75
	Decide which average is the most representative of the majority of the data values	84
	Decide on the most appropriate procedure or method to find the solution to the question or to complete a task	114
	Decide which method will be the most appropriate to compare the costs involved in the contracts	112
	Decide on an appropriate scale in which to draw a picture or build a model, and then complete the project	124
Make sense/engage with context	Rounding numbers depending on the context	30
	Making sense of situations involving: costs, tariffs, consumption, calculations of estimated traveling times, distance, speed, conversions and any other problems in the context of various topics.	33
	Making sense of situations involving: discount, tax, budgets, marks, estimating measurement quantities, expressions of probability	34
	Making sense of contexts and problems involving various topics	32
	Investigate and describe a variety of different types of graphs in order to develop a feel for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
	Make sense of, participate in and contribute to the twenty-first century world	8
	Make sense of real-life contexts	8
	Explore and make sense of appropriate contexts	9
	Make sense of any context, whether the context is familiar or not	9
	Learners are expected to make sense of, and the content and skills needed to make sense of those contexts	10

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Make sense of any context or problem in which these concepts have application	36
Making or critiquing an argument	Develop opposing arguments using the same summarised and/or represented data	88
	Critique the government's free water policy in terms of the findings of this project	69
	Evaluate and critique the validity of expressions and interpretations of probability presented in newspapers and other sources of information	94
	The learner should critique the decision	113
	Critique the scale in which an object has been drawn and offer an opinion as to a more appropriate scale	124
	Critique a proposed travel route in relation to distance, estimated travelling times, etc, and suggest and justify possible alternative routes	124
	Critique the design of a structure shown on a plan	124
	Analyse a model and critique the layout of the structure shown in the model	125
Manage situations / Control	Critique the questions/layout of a questionnaire/survey	126
	Critique the use of references to probability values in newspaper articles	127
	Organise and manage themselves and their activities responsibly and effectively	5
	Manage finances	51
	Monitor and manage mass (weight)	65
Model situations mentally and formally	Using tables and/or spreadsheets to construct a model of a loan scenario	57
	Make decisions regarding appropriate stopping points during a journey based on considerations of fatigue, petrol consumption, travelling time, etc.	124
Probe	Investigate the effect of changes in the interest rate on the loan and the impact of increasing the monthly repayment on the real cost of the loan	116

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Investigate, through research, the various costs involved in manufacturing an item, and decide on an appropriate selling price for the item	121
	Investigating impact of rounding	30
	Investigate and describe the impact of increasing the monthly repayments on the total cost of the loan/investment	121
	Investigate through calculation how the tax rebate value is determined	122
	Investigate the effect that an increase in salary has on increased tax payments	123
	Investigate and describe a variety of different types of graphs in order to develop a feel for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
	Investigate, describe and explain shapes of graphs in relation to scenarios	32
	Investigate budgets and income-and-expenditure statements	53
Reason and think / Deductive thinking / Logical thinking / Thinking Mathematically and strategizing / Thinking with mathematics	Identify and solve problems and make decisions using critical and creative thinking	6
	Discuss reasons why a particular size for a particular grocery item may be the most cost-effective	33
	Explore the possible reasons for food price inflation and the impact of this inflation on the people who buy food from these shops	59
	Find reasons for differences in tax values calculated using tax deduction tables and tax brackets	59
	Reasoning and reflecting	109
	Calculate the mean, median and modal average for a set of data and decide with reasons which average provides the most accurate representation of the data	126
	Ability to reason, make decisions, solve problems, manage resources, interpret information, schedule events and use and apply technology	8
Reason in numerical, data, spatial and chance settings	Reasoning, determining and discussing the most cost-effectiveness	33

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Seeing connections	Make connections between plans	124
	Connect the features shown on elevation plans with features and perspectives shown on a floor plan of the same structure	77
Understand	Interpret, understand and use different numbering conventions	28
	Understand situations and solve problems in scenarios involving Finance, Measurement, Maps, plans and other representations of the physical world, Data handling and Probability	21
	Understanding graphs that tell a story	22
	Interpret, understand and use different numbering conventions in contexts	28
	A proper understanding of the problem should be developed	30
	Rounding numbers with a proper understanding	30
	Perform calculations with an understanding	31
	Understand situations involving cost, tariffs, consumption, discount, tax budgets, market, etc	33-34
	Understanding relationships	41
	Understanding that tables, graphs and equations can all describe the same relationship, but in different ways	43
Validate	Analyse a payslip and show how the values on the payslip have been determined, including the UIF	59
	Prepare a budget to show the projected cost of painting the classroom	78
	Use a given formula to show how the amount charged for electricity consumption shown on the bill has been determined	120
	Draw graphs, without scaffolded or guiding questions, to show the costs involved in producing an item and money generated from the sale of the item	121
Skill 4: Statistical application		
Ask the right questions about data	Ask questions about the way in which data has been collected, organised, summarised and represented to reveal possible sources of error/bias/misinterpretation	87

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Assess the quality of the information, assessing claims	Analysing conclusions in terms of each stage of the statistical cycle to determine the reliability and validity of the conclusions	88
	Assessing products making statements regarding probability	91
	Recognise that error in measurement can make a large difference to an answer	26
	Recognising the possible effect of rounding values within a calculation on the final calculated answer	29
	Ask questions about the way in which data has been collected, organised, summarised and represented to reveal possible sources of error/bias/misinterpretation	87
Drawing inference from data	Learner is required to make inferences	116
Engage meaningfully with personal, social and political issues	Relate to daily life, the workplace and the wider social, political and global environments	8
Find information	Collect, analyse, organise and critically evaluate information	5
	Visit a supermarket and record pricing and size/weight/volume information for different grocery items	33
	Collect pricing information on a similar type of savings account at different banks	55
Interpret data	Interpret graphs representing situations involving direct and inverse proportion	32
	Interpret and analyse representations	43
Predict	Probability in weather predictions	24
	Probability in games with coins and dice, and weather predictions	24
	Analyse inflation figures to predict possible adjustments to building costs	78
	Making predictions about the outcome of an event	92
	Predict the trend of an outcome over a long period of time	92
	Recognise the difference between predictions that are based on knowledge and intuition about a situation	92

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Predict with certainty what the outcome of the match will be	93
	Decision, opinion or prediction about a particular scenario based on calculations in a previous question or on given information	116
Process, respond and think about numeric, quantitative, spatial, statistical, mathematical information	Investigate and describe a variety of differently types of graphs in order to develop a fell for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
Recognise the difference between correlation and causation		
Recognise the difference between randomised experiments and observational studies		
Statistical reasoning	Make a deduction about whether collected information is biased or valid based on the structure of instrument used to collect the data and the way in which the data was collected	126
	Explain with justification whether data is discrete or continuous	126
	Analyse data organised in tables and make deductions about trends in the data	126
	Analyse a table, graph or chart and explain or critique the use of probability values	127
Understand, predict and control situations important to their lives	Analyse inflation figures to predict possible adjustments to building costs	78
	Making predictions about the outcome of an event	92
	Predict the trend of an outcome over a long period of time	92
	Recognise the difference between predictions that are based on knowledge and intuition about a situation	92
	Predict with certainty what the outcome of the match will be	93
	Decision, opinion or prediction about a particular scenario based on calculations in a previous question or on given information	116

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Interpret, understand and use different numbering conventions	28
	Understand situations and solve problems in scenarios involving Finance, Measurement, Maps, plans and other representations of the physical world, Data handling and Probability	21
	Understanding graphs that tell a story	22
	Interpret, understand and use different numbering conventions in contexts	28
	A proper understanding of the problem should be developed	30
	Rounding numbers with a proper understanding	30
	Perform calculations with an understanding	31
	Understand situations involving cost, tariffs, consumption, discount, tax budgets, market, etc	33-34
	Understanding relationships	41
Weighing evidence / Compare	Decide which method will be the most appropriate to compare the costs involved in the contracts	116
	Compare solutions to a problem expressed in different units and make a decision about what unit is the most appropriate or useful for the particular context in which the problem is posed	123
	Comparing prices, data values in tables and on a graph	33, 34
	Comparing two different items	35
	Determining cost-effectiveness	33
	Conduct an experiment to compare the experimental probability of an event to its theoretical probability	127
	Compare differences in the rates of change between the dependent and independent variables for each of the relationships	45
	Compare different representations of multiple sets of data and explain differences	87
	Compare the probability values for two experiments	95
	Using calculations to compare income and expenditure values for a business in order to determine whether the business is in a healthy financial position	116

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Comparing bank charges on two different types of accounts for various transactions and making a decision about the most suitable account for an individual with particular needs	116
	Constructing a table to model a loan scenario, taking into account the interest calculated on the loan, the monthly repayment and the closing balance on the loan every month	116
	Using the model of the loan scenario to investigate the effect of changes in the interest rate on the loan and the impact of increasing the monthly repayment on the real cost of the loan	116
	Designing two different types of boxes for packaging an item, comparing the boxes in terms of wasted space (volume) and materials (surface area), and making a decision about the most cost-effective box for packaging the item	116
	Skill 5: Communication	
Communicate findings visually, verbally, orally	Communicate solutions using appropriate terminology, symbols and units	21
	Communicate effectively using visual, symbolic and/or language skills in various modes	5
	Communicate decisions using terminology (both mathematical and non-mathematical) appropriate to the context	9
	Clearly state workings and methods used for solving a problem	
	Investigating, understanding and describing graphs using every day and/or familiar terminology	37
	Explain shapes of graphs in relation to scenarios	32
Communicate simple quantitative ideas in English	Communicate effectively using visual, symbolic and/or language skills in various modes	5
	Complete the task presented in the instructions and/or explain what the instructions mean and/or represent, using everyday language	76
	Communicate decisions using terminology (both mathematical and non-mathematical) appropriate to the context	9
Communicate what Mathematics reveals	Communicate decisions using terminology (both mathematical and non-mathematical) appropriate to the context	9

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
Communication	Communicate effectively using visual, symbolic and/or language skills in various modes	5
	Complete the task presented in the instructions and/or explain what the instructions mean and/or represent, using everyday language	76
	Communicate decisions using terminology (both mathematical and non-mathematical) appropriate to the context	9
Construction, communication and evaluation of arguments	Develop opposing arguments using the same summarised and/or represented data	88
Interpret, apply and communicate mathematical information	Investigating, understanding and describing graphs using every day and/or familiar terminology	37
	Investigate and describe a variety of differently types of graphs in order to develop a fell for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
	Interpreting and analysing data	88
	Interpret newspaper articles, real bank statements, real plans and other authentic resources, rather than contrived problems containing only a semblance of reality	108
	Interpret graphs showing the cost of production and income generated from the production and sale of an item, and use the graphs to make decisions about the business	121
	Interpret time values on a bus timetable to determine departure, arrival and travelling times	123
	Devise and apply both mathematical and non-mathematical techniques and considerations in order to explore and make sense of any context, whether the context is familiar or not	9
	Apply addition and multiplication facts	29
	Communicate solutions using appropriate terminology, symbols and units	21
	Communicate effectively using visual, symbolic and/or language skills in various modes	5

Skill described in literature review of 'Quantitative Literacy'	Skill described in Mathematical Literacy CAPS	CAPS Page Reference
	Communicate decisions using terminology (both mathematical and non-mathematical) appropriate to the context	9
Language, reading and comprehension / Read, write and engage with numerical information	Describing graphs using every day and/or familiar terminology	37
	Read through and answer questions relating to the Tax Pocket Guide brochure issued by SARS	50
	Read information directly from a given questionnaire/survey	126
Representation	Representing and comparing data values in tables and graphs	34
	Representations of relationships in tables, equations and graphs	41
	Representing data	86
	Representations for determining possible outcomes	93
	Interpret graphs representing situations involving direct and inverse proportion and illustrating the difference between the two types of proportion	32
	Draw graphs to represent different scenarios	32
	Representing and/or comparing data values in tables and on a graph	34
Use written and graph source material	Investigate and describe a variety of different types of graphs in order to develop a fell for working with graphs and an understanding that graphs tell a story and present a message to the reader.	37
Verbal / Interpretive	After interpreting the floor plans of a house, build a scale model and perform perimeter, area and volume calculations in the context of fencing, paint, concrete, etc.	78
	Interpreting and analysing data	82
	Interpret quartile values, inter-quartile range values, and box-and-whisker diagrams in order to make deductions regarding trends in the data	85
	Interpret and read values from a pie chart and, if necessary, explain how the sizes of the different segments of a pie chart have been determined	86
	Interpret the plot and explain what the shape of the plot signifies in terms of the spread of the data values	86

ANNEXURE 2: A COMPARISON OF THE MATHEMATICAL KNOWLEDGE/CONTENT IN 'QUANTITATIVE LITERACY' AND THE MATHEMATICAL KNOWLEDGE/CONTENT IN THE CURRICULUM AND ASSESSMENT POLICY STATEMENT FOR MATHEMATICAL LITERACY IN SOUTH AFRICA.

	CAPS	Literature review of 'Quantitative Literacy'
Basic skills	Interpreting and communicating answers and calculations	
	Numbers and calculations with numbers	Arithmetic/numeric calculations, Proportional reasoning, e.g. in ratio problems
	Patterns, relationships and representations	Linear and exponential graphs, Pattern recognition, Variables and relations, Solving non-linear equations, Working with models of linear and exponential growth
Application topics	Finance	Production rates and price schemes
	Measurement	Extrapolation and fitting lines or curves to data, Area of rectangle and circle and volume of rectangular solids, spheres, cylinders and cones, Measurement
	Maps, plans and other representations	Space and visualisation
	Data handling	Recording data, Statistical analysis (measures of central tendency and dispersion)
	Probability	Probability, Combinatorics, e.g. combinations and permutations, expressed in tree diagrams and useful in probability

High school mathematics marks as an admission criterion for entry into programming courses at a South African university¹

Duan van der Westhuizen, University of Johannesburg, South Africa

Glenda Barlow-Jones, University of Johannesburg, South Africa

ABSTRACT

In this study, the assumption that good performance in mathematics in the final school year could be used as a pre-entry requirement to programming courses at universities in South Africa, is challenged. The extant literature reports positive relationships between mathematics performance and success in programming courses. As computer programming modules in higher education institutions (HEIs) are typically characterised by low success rates, it becomes important to eliminate potentially erroneous entry requirements. The low success rate in programming modules is ascribed to the abstract nature and content of programming courses, and the inadequacy of pre-university education to prepare students for the cognitive skills required for success in such programmes. This paper reports on a single independent variable, 'performance in high school mathematics', and its relationship to performance in two computer programming courses. The dataset comprised the school marks of four cohorts of students who were enrolled for the programming modules between 2012 and 2015. Firstly, we computed the point-biserial correlation between a dichotomous variable that indicated whether students had mathematics as a subject in Grade 12 or not, and their performance in the programming modules. Once we established that a relationship existed, the marks achieved in the final school year for mathematics, and performance in two programming modules were correlated. Results indicated that the school mathematics marks correlate only marginally, and that correlations were not significant, with performance in the two programming courses. We also correlated the school mathematical literacy marks with performance in the two programming courses, and found that a strong positive correlation that was significant existed with the second semester programming course. We conclude that the mark achieved for school mathematics cannot be considered as a valid admission criterion for programming courses in the South African context.

Keywords: mathematics, higher education, enrolment criteria, computer programming

INTRODUCTION

This paper reports on the relationship that exists between a single variable, 'performance in school mathematics', and performance in two first-year level programming courses at a university in Johannesburg, South Africa. The exploration of the variable forms part of a larger project that attempts to isolate variables that influence the readiness of school leavers in South Africa to enrol for, and be successful in, programming

¹ Date of Submission 18 January 2015

Date of Acceptance 4 June 2015

courses. As part of our investigations, we have extensively explored a number of pre-entry variables that could influence the proclivity of school leavers to be successful in the university courses. These include: living conditions, living standard means, schooling variables like teacher pedagogical stances, access to learning materials, access and use of ICT, the development of critical thinking skills, (also at home), cultural views on authority, and the achievement of learners in their final year school examinations.² In this paper, we report on a single variable, which is the final scores achieved by students in mathematics at the school level, and how these scores relate to their performance in the programming modules. As will become evident subsequently, our findings contradict knowledge in this regard. The extant literature reports positive relationships between mathematics performance and success in programming courses. Our findings also contradict what common sense expected us to find. How could this be? We acknowledge that the examination of a single independent variable is insufficient to explain the success (or lack of success) of the students who enrol for these modules. Yet, the magnitude of the evidence that our results contradict, places the very validity of the variable that we examined in question. The implication of that is virtually unthinkable: Can the performance of learners in their subjects be an inaccurate reflection of their abilities, and can these performances therefore not be scientifically related to their capacity to be successful in higher education courses?

NATIONAL CONTEXT

In South Africa, learners in their last three years of schooling (Grade 10 – 12) have to take seven subjects. Four of these subjects are mandatory: English (either as first or second language), a second approved language (again, either as first or second language), Life Orientation, and either Mathematics or Mathematical Literacy. Additionally, learners must select three other subjects from a host of disciplines. These include subjects like Geography, Physical Sciences, Life Sciences, Agricultural Sciences, History, Accounting, Business Studies, Economics, etc. (Department of Basic Education, 2015).

At the end of the academic year, Grade 12 learners write national examinations in all their subjects. These national examination papers are set by the Department of Basic Education (DBE). The examination scripts (or other assessment artefacts like art work) are marked and moderated by independent panels of markers, who are teachers who need to apply and meet certain criteria, before being appointed as a marker. The final marks that are achieved for each subject is expressed as a percentage. The final marks for each subject constitutes a combination of marks earned during the school year, and the marks achieved during the national examinations. The marks of six subjects (Life Orientation is excluded) are used to calculate an 'Admission Point Score' (APS), as is seen in Table 1 (IEB, 2015).

Table 1:
National Senior Certificate achievement levels

%	100-80	79-70	69-60	59-50	49-40	39-30	29-20	19-10	9-0
NSC Level	7	6	5	4	3	2	1	1	1
Symbol	A	B	C	D	E	F	G	H	I

Source: Adapted from Schoer et al. (2010)

² In a separate, concurrent project, we are considering the results of our investigations, as we attempt to derive design principles, using design-based research methodologies, to re-design the pedagogical approaches by which these two first-year level programming courses are taught.

Previously, universities used the APS score to determine whether, and to which programmes, prospective students may be admitted. Minimum APS scores are required for admittance to particular programmes, and may differ between institutions. Programmes that are considered to be difficult to be successful in may require higher APS scores than programmes that are considered easier. For example, admission to humanities programmes may require an APS score of 30, whereas admission to engineering programmes may require a higher APS score of 35 (University of Pretoria, 2015a, 2015b respectively). In addition, a sub-minimum mark in specific school subjects may be required before admission to certain programmes is considered.

Lately however, universities do not consider the APS score as an accurate measure for admission to their higher education programmes (Hunt, Rankin, Schoer, Nthuli & Sebastiao, 2009) for a number of reasons. The validity of Grade 12 final examination results are being questioned nationally by the public, educational experts and by universities. The marks of students who come from 'disadvantaged' schools are particularly questioned for a number of reasons (Jenkins, 2004; Marnewick, 2012). Firstly, it is believed that matriculation results are politically manipulated to show an improved performance of the school education system overall, and especially so since democratisation in 1994. Secondly, the marks achieved by learners undergo a process of standardisation by Umalusi, the Council for Quality Assurance in General and Further Education and Training after a process of a review of the marks in order 'to mitigate fluctuations in learner performance that are a result of factors within the examination process itself'. Therefore, marks may be adjusted upwards or downwards by as much as 10% in any subject that was written during the national examination to align with historical performance trends in the particular subject (Parliament.gov.za, 2014). Thirdly, reports in the local press indicate rife large-scale cheating during the examinations by learners. Approximately 5300 learners were investigated for irregularities during the 2014 National Senior Certificate (NSC) examinations (SAnews, 2015). Umalusi's moderation processes identified 'group copying' in maths, economics and business studies. It was also found that there had been 'evidence of possible assistance by an invigilator or exams official' in the mathematics paper, which was written by 174 candidates (Times Live, 2015). Finally, according to the South African Democratic Teachers Union (SADTU), 'Schools are manipulating the learner promotion and progress because of pressure to produce better Senior Certificate results' (2015). It has been reported that schools manipulate marks, or alternatively, that the progression of learners through the grades are artificially managed by holding learners back in some grades and advancing them through others.

Annually, the examination results are published in local newspapers, and learners may on the same day collect their official results and certificates from their former schools. Typically, a news conference is called by the ministry, and the official 'matric pass rate' is made known. The official pass rate that has steadily been rising over the past number of years, warrants further scrutiny, warns Van der Westhuizen (2013). He points out that the 'Class of 2012' had a published pass rate of 73.9%. However, this number disregards the 620 000 learners who have dropped out of the educational system since 2001, the year that this cohort of students entered formal schooling. Therefore, the success rate of the cohort is a more sobering 37%. This alternative perspective on the pass rate raises further questions on the quality of South African school education.

Certainly, the performance of South African school learners in international benchmark tests supports the concerns raised above. South African learners participated in three international benchmarking studies during the past decade: Trends in Mathematics and Science Studies 2011 (TIMSS), Progress in International Reading Literacy (PIRLS) and Southern and Eastern Africa Consortium for Monitoring Education Quality (SACMEQ). The results show that South African learners consistently perform poorly in comparison to its more impoverished neighbours, and very poorly in comparison to developing countries in other parts of the world (Taylor, Fleisch & Schindler, 2008). The Global Information Technology Report of 2013 ranks South Africa 143 out of 144 countries for mathematics and science education and 140 out

of 145 for overall quality of their education system. This is worse than many of the world's poorest nations in mathematics and science; only Yemen ranks lower (World Economic Forum, 2013).

University dropout rates in South Africa is alarming. By the end of the first year, 30% of students will have dropped out. A year later, a further 20% will drop out. Van Zyl reports that 41% of students who enter higher education will eventually drop out (News24, 2015). University academics report that first-year students are simply not ready for the demands of higher education.

Against this background, 'The National Benchmark Tests (NBTs) were commissioned by Higher Education South Africa (HESA) with the task of assessing the academic readiness of first-year university students as a supplement to secondary school reports on learning achieved in content specific courses' (NBT, 2011). The NBTs assess competency in Academic Literacy (AL), Quantitative Literacy (QL) and Mathematics (MAT), all which may directly impact a first-year university students' likelihood of success (Marnewick, 2012). The results of the NBTs inform universities about the level of academic support that students may need to be successful in their chosen field of study. The results are also used by universities for programme planning. Most universities now require prospective students to write the NBT examination, and will admit students to their programmes based on the scores obtained in those examinations.

Since 2008, educational policy in South Africa dictates that for the last three years of schooling, learners have to select either mathematics or mathematical literacy as one of the seven compulsory subjects. Prior to this, mathematics was not a compulsory subject, and those learners who chose it could do so either at a 'higher grade' or 'standard grade' level (Pasensie, 2012). Only 60% of students opted to take mathematics for the final three years of schooling between the years 2000 and 2005. Of those, the vast majority opted for the standard grade level, and only 5.2% of all learners in the country passed mathematics at the higher grade level (Clark, 2012). The new curriculum that was introduced in 2008 abandoned the level options of higher grade or standard grade for each subject. A new subject, mathematical literacy, was introduced, and learners must choose between mathematics and mathematical literacy for Grades 10–12 (Spangenberg, 2012). Mathematical literacy equips and sensitises learners with an understanding of the relevance of mathematics in real-life situations (Department of Basic Education, 2011a). Typical topics in mathematical literacy include learning how to calculate income tax, how to calculate the cost of buying a house, including calculating transfer fees, legal fees and bond repayment amounts (Clark, 2012). Mathematical literacy creates a consciousness about the role of mathematics in the modern world and is therefore driven by practical applications. The subject develops the ability and confidence of learners to think numerically in order to interpret daily situations (Department of Basic Education, 2011a). Mathematical literacy was specifically introduced as an intervention to improve the numeracy skills of South African citizens, in response to poor performance in mathematics in the past (Pasensie, 2012). For many learners, especially learners from rural areas, mathematical literacy may be their only opportunity of acquiring any mathematical skills at all. Some of the differences between these two subjects are tabulated in Table 2.

*Table 2:
Focus differences between Mathematics and Mathematical Literacy as prescribed by the National Curriculum Statement*

Example content from the Mathematics curriculum	Example content from the Mathematical Literacy curriculum
Number and number relationships: <ul style="list-style-type: none"> Convert between terminating or recurring decimals Fluctuation foreign exchange rate 	Number and operations in context: <ul style="list-style-type: none"> Percentage Ratio Direct and inverse proportion Scientific notation

Example content from the Mathematics curriculum	Example content from the Mathematical Literacy curriculum
Functions and algebra: <ul style="list-style-type: none"> Graphs to make and test conjectures and to generalise the effects of the parameters a and q on the graphs Algebraic fractions with monomial denominators Linear inequalities in one variable Linear equations in two variables simultaneously 	Functional relationships: <ul style="list-style-type: none"> Numerical data and formula in a variety of real-life situations, in order to establish relationships between variables by finding the dependent variable and the independent variable.
Space, shape and measurement: <ul style="list-style-type: none"> Volume and surface area of cylinders Co-ordinate geometry The trigonometric functions $\sin\theta$, $\cos\theta$ and $\tan\theta$, and solve problems in two dimensions by using the trigonometric functions in right-angle triangles 	Space, shape and measurement: <ul style="list-style-type: none"> International time zones Circles Draw and interpret scale drawings of plants to represent and identify views
Data handling and probability: <ul style="list-style-type: none"> Measures of dispersion (range, percentiles, quartiles, interquartile and semi-interquartile range) Frequency polygons Venn diagrams 	Data handling: <ul style="list-style-type: none"> Investigate situations in own life by formulating questions on issues such as those related to social, environmental and political factors, people's opinions, human rights and inclusivity Collect or find data by appropriate methods (e.g. interviews, questionnaires, the use of databases) suited to the purpose of drawing conclusions to the questions Representative samples from populations

(Spangenberg, 2012)

Performance in mathematics has traditionally been considered a primary predictor of success in programming courses, and several studies showed that a positive relationship exists between performance in mathematics and success in computer programming courses (Byrne & Lyons, 2001; Wilson & Shrock, 2001; Gomes & Mendes, 2008; Bergin & Reilly, 2005). Mathematics as an academic subject which focuses on abstract, deductive reasoning and problem solving, is a discipline that is required in the scientific, technological and engineering world (Venkat, 2007) where the ability to 'think logically and systematically, reason, judge, calculate, compare, reflect and summarise' (Department of Basic Education, 2011b) is of paramount importance. Bohlmann & Pretorius (2008: 43) claim 'the conceptual complexity and problem-solving nature of Mathematics make extensive demands on the reasoning, interpretive and strategic skills of learners'. The skills that are associated with mathematics learning are considered essential for learning programming during computer programming courses. There is a common belief that a student who does well in high school mathematics will also do well in Computer Science (Goold & Rimmer, 2000; Spark, 2005). Gomes & Mendes (2008) showed that the majority of the novice programming students in their study did not possess the necessary basic mathematical conceptual understanding that was expected, and that in turn affected their problem-solving ability, and resulted in poor programming skills development. Spark (2005) showed that the level (previously Higher Grade and Standard Grade) at which mathematics was taken, and not the marks that they achieved, more accurately reflected their ability to learn how to programme. Students who took mathematics on the standard grade did not perform as well in the programming courses as the students who took mathematics at the higher grade.

How did South African learners perform in mathematics and mathematical literacy after 2010, when the first matriculants of the new curriculum wrote the national examinations? Table 3 and Table 4 tabulate this data.

Table 3:
Learners' performance in Mathematical Literacy for 2011-2014

Year	Total Grade 12 Learner Enrolment	Wrote	Pass 40-100%	% Pass 40-100%
2011	511 038	275 380	178 899	65.0
2012	527 572	291 341	178 498	61.4
2013	575 508	324 097	202 291	62.4
2014	550 127	312 054	185 528	59.5

(Department of Basic Education, 2015)

Table 4:
Learners' performance in Mathematics for 2011-2014

Year	Total Grade 12 Learner Enrolment	Wrote	Pass 40-100%	% Pass 40-100%
2011	511 038	224 635	61 592	30.1
2012	527 572	225 874	80 716	35.7
2013	575 508	241 509	97 790	40.5
2014	550 127	225 458	79 050	35.1

(Department of Basic Education, 2015)

It is clear that a small proportion of the total learner enrolment in Grade 12 selected mathematics as a subject. This has severe implications for the training of programmers, as mathematical literacy is not considered appropriate for selection for programming courses at several universities.

Several questions arise from the aforementioned discussion. Whereas it would almost be impossible to establish causal relationships between performance in mathematics at the school level, and success in programming courses, in the context of the South African educational system it becomes important to establish whether any relationships exist at all between performance in school subjects and success in higher education courses. If no such relationships can be quantified and verified, it would mean that the use of school exit performances cannot be used as criteria to grant access to higher education, and that other mechanisms would have to be found to predict or anticipate success at the university level for the school leavers of the South African school education system.

The purpose of this paper therefore is to establish what correlational relationships exist between performance in school mathematics, and success in first-year level programming courses. This will enable us to establish the validity of using the school subject results as an admission criterion to programming courses.

THE COURSES

The National Diploma: Information Technology (NDIT) is offered by Universities of Technology (formerly known as 'Technikons') and comprehensive universities across South Africa. Admission to the programme is dependent on the performance of school leavers during the National Senior Certificate Examination

(NSC). The admission criteria for the diploma at the urban university in Johannesburg where this study was conducted, required a minimum mark of 40% for mathematics, or 70% for mathematical literacy. In addition, applicants had to pass English with a mark of higher than 50%. An APS score of 24 with mathematics or 26 with mathematical literacy is further required.

The programming modules in the first year are *Development Software 1A* (DSW01A1) presented in the first semester of the academic year (February – May) and *Development Software 1B* (DSW01B1) presented in the second semester (July – November). These courses cover the basic programming principles that are practically applied in Java. The modules provide an introduction to a programming environment, assuming that the student does not have any previous knowledge or experience of any programming languages. The course is meant for beginner programmers and allows the students to build useful programs quickly while learning the basics of structured and object-oriented programming techniques. The course is also aimed at developing the students programming and logic abilities. These two modules are prerequisites for all second-year programming modules.

METHOD

The data of 393 students who were enrolled for the two first-year courses between 2012 and 2015 were extracted from the university administrative system, and exported to a Microsoft Excel format. The variables that were extracted were student number, year of enrolment, final year of schooling results for all school subjects, and performance in the two first-year level programming courses. The data were scrutinised for anomalies, and cases were removed where data were incomplete, where students dropped out, or where students were refused admission to the final examination for not complying with minimum pre-examination performance criteria. A correlational analysis between the performances in the two programmes among the four year groups found that the year of enrolment did not significantly influence the correlations that were computed between 'performance in school mathematics', and 'performance in the two first-year level programming courses'. Therefore, the enrolment across the four cohorts was treated as a single data set.³ No other contextual variables were identified that may have impacted on the performance in the two courses. The courses were taught by the same lecturer, using the same curriculum, and the same pedagogy. Assessment practices are standard, and the examinations are internationally benchmarked. The department admitted students to the programme who did mathematical literacy as a school subject and for which they achieved 70% or higher. Students who were admitted based on their school mathematics marks (n=274) outnumbered students who were admitted based on their mathematical literacy marks (n=119).

All the guidelines prescribed by relevant ethics committees were adhered to and permission was granted to conduct the research by the Faculty of Education Ethics Committee. During the research, utmost care was taken to ensure that data were recorded and analysed as accurately as possible. Only student numbers were used to identify respondents in order to ensure student anonymity and to assist the researchers in obtaining information about their performance in their programming modules, which was essential for the research. No personal interactions took place with students.

RESULTS

SPSS V.22 was used to perform the analyses. The following variables were used for analysis: 'school mathematics mark', 'school mathematical literacy mark', 'DevSoftware 1A performance' and 'DevSoftware 1B performance'. We created two additional dichotomous variables 'Mathematics –Yes/No', and 'Mathematical Literacy –Yes/No' to isolate students who were admitted with mathematics as a school

³ The 2015 dataset contains data for Software Development 1A only.

subject to the programme, as opposed to those who were admitted with mathematical literacy. Table 5 tabulates the combined descriptive statistics for these variables across the four cohorts.

Table 5:
Combined descriptive statistics for variables

	n	Min	Max	Mean	SD	Skewness		Kurtosis	
						Statistic	Std. Error	Statistic	Std. Error
DevSoftware 1A	361	29	91	59.53	11.356	.250	.128	-.109	.256
DevSoftware 1B	219	29	92	64.68	12.361	-.143	.164	-.381	.327
School Mathematics	274	16	80	48.98	9.165	.658	.147	1.766	.293
School Math Literacy	104	41	97	74.58	7.536	-.585	.237	3.562	.469

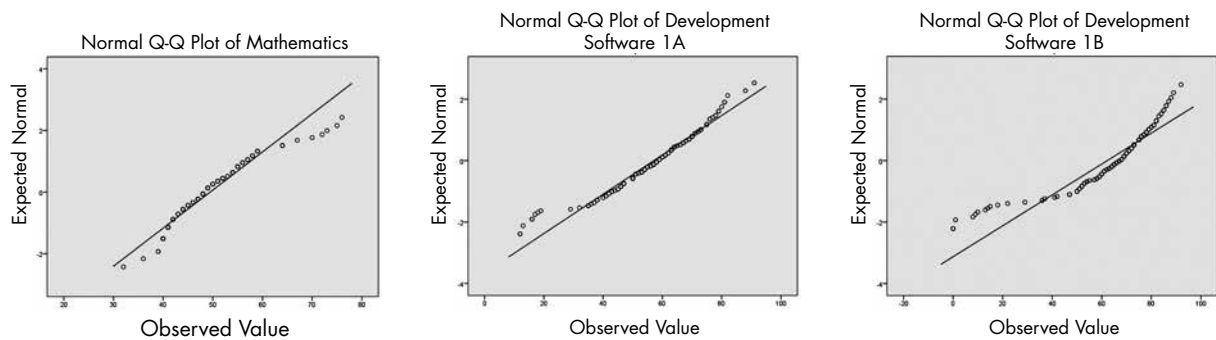
Table 5 shows that students performed better in Development Software 1B ($M = 64.68$) than they did in Development Software 1A ($M = 59.53$). This could partially be accounted for by students who dropped out due to poor performance in the first semester course, and whose marks brought the mean down. There were noticeably fewer students enrolled for the Development Software 1B course. There is also significantly less variation in the data for the 'school mathematics mark' ($SD = 9.16$) and 'school mathematical literacy mark' ($SD = 7.53$) variables than there is for 'DevSoftware 1A performance' ($SD = 11.35$) and 'DevSoftware 1B performance' ($SD = 12.36$). The smaller variances for the school marks based variables can partially be explained by the admission requirements to the programmes, eliminating data points below 40% (for mathematics) and 70% (for mathematical literacy) that are required for admission to the programme. Table 6 tabulates the means for each variable by cohort.

Table 6:
Combined descriptive statistics for variables by cohort

	2012			2013			2014			2015		
	n	Mean	SD	n	mean	SD	n	mean	SD	n	mean	SD
DevSoftware 1A	74	58.72	13.82	86	58.51	8.666	120	60.29	10.02	81	60.21	13.17
DevSoftware 1B	56	68.95	9.70	67	56.67	11.380	96	67.77	11.85	-	-	-
School Mathematics	61	48.62	9.18	60	49.03	8.602	100	48.28	8.88	53	50.64	10.27
School Math Literacy	31	73.03	10.00	24	76.83	5.577	32	74.25	7.14	17	74.82	4.667

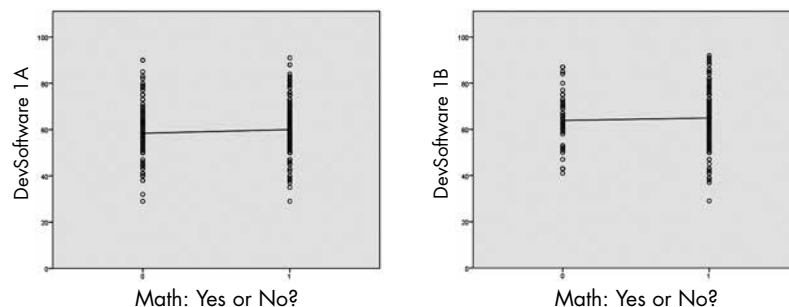
In order to establish the normality of the data, we decided to perform a visual inspection of the distribution of the data for three variables by generating Q-Q plots (quantile-quantile plots) for each variable: 'school mathematics mark', 'DevSoftware 1A performance' and 'DevSoftware 1B performance'. These are represented in Figure 1. It is immediately apparent that none of the data for any of the three variables could not be considered as being normally distributed.

Figure 1:
Q-Q plots of normality for each variable



A point-biserial correlational analysis was computed between each of the dependent performance variables and the variable 'Mathematics –Yes/No', which indicated whether having a 'school mathematics mark' correlated with performance in the two programming modules. The results revealed that having 'school mathematics mark' slightly correlates with 'DevSoftware 1A performance' and is not significant at the 0.05 level ($r = .063$, $p > .05$). A similarly weak correlation exists between having a 'school mathematics mark' and 'DevSoftware 1B performance', which was not significant ($r = .038$, $p > .05$). Based on these results, we can state that there is a weak relationship between having a 'school mathematics mark' and performance in either of the two modules. Figure 2 illustrates these weak correlations.

Figure 2:
Point-biserial correlational analysis between each of the dependent performance variables and the variable 'Mathematics –Yes/No',



The weak correlations revealed by the point-biserial correlational analysis between having mathematics as a school subject and performance in the two programming modules was surprising. We computed another dichotomous variable, 'Mathematics Literacy –Yes/No'. This variable was correlated against performance in the two programming modules. The results of this analysis is tabulated in Table 7.

Table 7:
Point-biserial correlational analysis between Mathematical Literacy and Development Software 1A and Development Software 1B

		DevSoftware 1A	Math Literacy Yes or No?	DevSoftware 1B
DevSoftware 1A	Pearson Correlation	1	-.130*	.610**
	Sig. (2-tailed)		.014	.000
	N	361	361	219

		DevSoftware 1A	Math Literacy Yes or No?	DevSoftware 1B
Math Literacy Yes or No?	Pearson Correlation	-.130*	1	-.038
	Sig. (2-tailed)	.014		.579
	N	361	393	219
DevSoftware 1B	Pearson Correlation	.610**	-.038	1
	Sig. (2-tailed)	.000	.579	
	N	219	219	219

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The point-biserial correlational analysis yielded a strong positive correlation between having mathematical literacy and performance in Development Software 1B which was significant at the 0.01 level ($r = .610$, $p < .000$), whereas a slight negative correlation, yet significant at the 0.05 level was found to exist between having mathematical literacy and performance in Development Software 1A ($r = -.130$, $p < .000$).

We further computed the correlation between the variables 'school mathematics mark' and performance in each of the two programming courses. The results of these analyses are tabulated in Table 8 and Table 9.

Table 8:
Correlation between Mathematics and Development Software 1A

		Mathematics	Development Software 1A
School Mathematics Mark	Pearson Correlation	1	.129
	Sig. (2-tailed)		.157
	N	129	123
Development Software 1A	Pearson Correlation	.129	1
	Sig. (2-tailed)	.157	
	N	123	123

It is evident from Table 8 that for the students who enrolled for SoftDev1A, a weak, insignificant correlation ($r = .129$, $p > .05$) exists between the marks obtained in mathematics in high school and performance in the course.

Table 9:
Correlation between Mathematics and Development Software 1B

		Development Software 1B	Mathematics
Development Software 1B	Pearson Correlation	1	.153
	Sig. (2-tailed)		.113
	N	108	108

		Development Software 1B	Mathematics
Mathematics	Pearson Correlation	.153	1
	Sig. (2-tailed)	.113	
	N	108	129

It is evident from Table 9 that, for the students who enrolled for SoftDev1A, a weak, statistically non-significant correlation ($r = .153$, $p > .05$) exists between the marks obtained in mathematics in high school and performance in the course.

DISCUSSION AND CONCLUSION

The very notion that performance in mathematics at the school level can be correlated with performance in mathematics in HEIs is being re-examined internationally. For example, at the University of Limerick in Ireland, 31% of students who obtained distinctions in mathematics at the Leaving Certificate level, were diagnosed as being 'at-risk' in their higher mathematics courses. This points to international discrepancies between students' school-leaving mathematics examination results and mathematics comprehension post-school. This trend has been observed in the United Kingdom, Australia, the United States of America and in Ireland (Hourigan & O'Donoghue, 2007). In South Africa, a study by Maharaj & Gokal (2006) showed that there was no correlation between students' Grade 12 mathematics results and their performance in first-year Information Systems and Technology courses. Clearly a substantial discord exists between school leaving abilities in mathematics, and expected performance at the HEI level.

Therefore, it is not surprising that the findings of our study indicate that mathematics marks at the school level, in this context, could not be correlated with performance in programming courses at the university level at levels of significance. These results contrast those of Byrne & Lyons, (2001), Wilson & Shrock (2001), Gomes & Mendes (2008), and Bergin & Reilly (2005) who claimed that performance in mathematics can predict programming performance. This finding places the very notion of using school level exit marks as a criterion for admittance to university programmes in South Africa under the spotlight. It is important to note here that we are not claiming that ability in mathematics does not correlate with success in programming courses. Our position is that the mark that is used to express mathematical ability does not correlate with performance in programming courses. Therefore, the validity of the mark as being reflective of mathematical ability is questioned!

The majority of the students whose performance data were used in this research, were not required to complete the NBTs in order to acquire access to the NDIT. It will be useful when the requirement to complete NBT assessment is established and mandatory, to re-examine the relationship between those results and performance.

Language ability also plays a significant role in acquiring programming skills, and it may very well be that language and language comprehension ability may play a role here. The South African NBTs, may possibly be more accurate predictors of performance in programming courses, and research needs to be conducted on potential students and their NBT results in an attempt to determine a student's success in programming courses.

REFERENCES

Bergin, S. & Reilly, R. (2005) 'Programming: Factors that Influence Success' *SIGCSE '05*. February 23-27. St. Louis, Missouri, USA.

Bohlmann, C. & Pretorius, E. (2008) 'Relationships Between Mathematics and Literacy: Exploring Some Underlying Factors' *Pythagoras* 67 June pp.42-55.

Byrne, P. & Lyons, G. (2001) 'The Effect of Student Attributes on Success in Programming' ITiCSE 2001. *Proceedings of the 6th Annual Conference on Innovation and Technology in Computer Science Education*. pp.49-52. ACM New York, NY, USA ©2001

Clark, R. (2012) 'Maths vs Maths Literacy: The Continuing Debate' Posted on 9 January 2012. Reader Blog. <http://www.thoughtleader.co.za/readerblog/2012/01/09/maths-vs-maths-literacy-the-continuing-debate/> (Accessed 29 October 2013).

Department of Basic Education. (2011a) National curriculum statement. Grade 10–12 (General) Mathematical Literacy. Pretoria: DOE. <http://www.education.gov.za/LinkClick.aspx?fileticket=jB%2fjGQ35Ugl%3d&tabid=420&mid=1216>

Department of Basic Education. (2011b) *National curriculum statement. Grade 10–12 (General) Mathematics*. Pretoria: DOE. <http://www.education.gov.za/LinkClick.aspx?fileticket=QPqC7QbX75w%3d&tabid=420&mid=1216>

Department of Basic Education. (2015) *National Senior Certificate Examination Diagnostic Report 2014*. <http://www.education.gov.za/LinkClick.aspx?fileticket=hZL6MoEQvtQ%3D&tabid=36&mid=1548> (Accessed 10 June 2014).

Gomes, A. & Mendes, A. (2008) 'A study on student's characteristics and programming learning' In J. Luca & E. Weippl (Eds.) *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2008* pp.2895-2904. Chesapeake, VA: AACE. <http://www.editlib.org/p/28776>

Goold, A. & Rimmer, R. (2000) 'Factors Affecting Performance in First Year Computing' *ACM SIGCSE Bulletin Inroads* 32(2) June pp.39-43.

Hourigan, M. & O'Donoghue, J. (2007) 'Mathematical under-preparedness: the influence of the pre-tertiary experience on students' ability to make successful transition to tertiary level mathematics courses in Ireland' *International Journal of Mathematical Education in Science and Technology* 38(4) pp.461-476.

Hunt, I.K., Rankin, N.A., Schoer, V., Nthuli, M. & Sebastiao, C. (2009) 'Blind Admission? The ability of NSC maths to signal competence in university commerce courses as compared to the former SC Higher Grade Maths' University of the Witwatersrand, African Micro-Economic Research Unit. 22 October 2009. MPRA Paper No. 18075. <http://mpa.ub.uni-muenchen.de/18075/> Posted 26 October 2009 9:26 UTC. (Accessed 1 August 2013).

IEB. (2015) *National Senior Certificate*. <http://www.ieb.co.za/School/nsc.php> (Accessed 24 June 2015).

Jenkins, J.D. (2004) 'The Predictive Validity of the General Scholastic Aptitude Test (GSAT) for First Year Students in Information Technology' Mini-dissertation submitted to the Faculty of Education in partial fulfillment of the requirements for the degree of Master of Education (Educational Psychology) in the Department of Educational Psychology and Special Education at the University of Zululand, South Africa.

Maharaj, M.S. & Gokal, H. (2006) 'An Investigation into the Performance of First Year, First Entry Students in Information Systems and Technology in Relation to their Matriculation Results' *36th Annual Conference of the Southern African Computer Lecturers Association*. <http://www.sacla.org.za/SACLA2006/Papers/> (Accessed 4 December 2013).

Marnewick, C. (2012) 'The Mystery of Student Selection: Are There Any Selection Criteria?' *Educational Studies* 38:2 pp.123-137.

News24. (2015) 'South Africa's alarming university drop out rate' <http://businesstech.co.za/news/general/87770/south-africas-alarming-university-drop-out-rate/> (Accessed 24 June 2015).

NBT. (2011) *National Benchmark Tests Project*. <http://www.nbt.ac.za/> (Accessed 24 October 2013).

Parliament.gov.za (2014) Umalusi on standardising matric results. http://www.parliament.gov.za/live/content.php?Item_ID=1421

Pasensie, K. (2012) Briefing Paper 280: Matric 2011: Playing the Number Crunching Game Yet Again. January 2012. South Africa.

SADTU. (2015) 'Matric 2014: Schools manipulating learner promotion and progress – SADTU' <http://www.politicsweb.co.za/news-and-analysis/matric-2014-schools-manipulating-learner-promotion>

SAnews. (2015) 'Probe into matric group copying continues' <http://www.sanews.gov.za/south-africa/probe-matric-group-copying-continues> (Accessed 25 June 2015).

Schoer, V., Ntuli, M., Rankin, N., Sebastiao, C. & Hunt, K. (2010) 'A Blurred Signal? The usefulness of National Senior Certificate (NSC) Mathematics Marks as Predictors of Academic Performance at University Level' *Perspectives in Education* 28(2) pp.9-18.

Spangenberg, E.D. (2012) 'Thinking styles of Mathematics and Mathematical Literacy learners: Implications for subject choice' *Pythagoras* 33(3) Art. #179, 12 pages. <http://dx.doi.org/10.4102/pythagoras.v33i3.179>

Spark L. (2005) 'Matric Maths as a Predictor of Success in Information Systems A Study of Information Systems Students at the University of the Witwatersrand' *Proceedings of the 35th Conference of SACLA* pp.268-271. Kasane, Botswana.

Taylor, N., Fleisch, B. & Shindler, J. (2008) 'Changes in Education Since 1994' <http://www.jet.org.za/publications/research/Taylor%20Fleisch%20Shindler%20Changes%20in%20Education%2015%20year%20review.pdf> (Accessed 3 July 2014).

Times Live. (2015) 'Matric cheats uncovered in seven out of nine provinces' <http://www.timeslive.co.za/local/2015/01/04/matric-cheats-uncovered-in-seven-out-of-nine-provinces>

University of Pretoria (UP). (2015a) Humanities Undergraduate Faculty Brochure. http://www.up.ac.za/media/shared/360/Faculty%20Brochures%202015%202016/fb-humanities-2015_16-final.zp42801.pdf (Accessed 24 June 2015).

University of Pretoria (UP). (2015b) Engineering, Built Environment and Information Technology Undergraduate Faculty Brochure. http://www.up.ac.za/media/shared/360/Faculty%20Brochures%202015%202016/fb-ebit-2015_16-final.zp42861.pdf (Accessed 24 June 2015).

Van der Westhuizen, D. (2013) 'Emancipation from fundamentalist teaching: how school inhibits ICT creativity and innovation' *Proceedings of the ISTE International Conference on Mathematics, Science and Technology Education* 21-24 October 2013. pp.199-218. Pretoria: UNISA PRESS.

Venkat, H. (2007) 'Mathematical Literacy - Mathematics and/or Literacy: What is Being Sought' *Pythagoras* 66 December 2007 pp.76-84.

Wilson, B.C. & Shrock, S. (2001) 'Contributing to Success in an Introductory Computer Science Course: A Study of Twelve Factors' *SIGCSE Bulletin* 33 pp.184-188.

World Economic Forum. (2013) *The Global Information Technology Report 2013. Growth and Jobs in a Hyperconnected World*. ISBN-13: 978-92-95044-77-7. www.weforum.org/gitr (Accessed 5 June 2013).

Social Development Theory: A case for multilingual tutorials (Mlts) in Law¹

Noleen Leach, Cape Peninsula University of Technology, South Africa

ABSTRACT

Poor throughput and high attrition rates increase the cost of training and decrease the admissions opportunities for school leavers in higher education. The poor performance of students in a first-year Law course in an Accounting programme at a university of technology contributed to this problem. English is the medium of instruction but the mother tongue of the majority of students is predominantly isiXhosa or Afrikaans and many of these students were struggling with the medium of instruction as well as the discourse of the discipline. Submersion schooling compounds the deeply ingrained weak interlanguages of students entering higher education, presenting a particular challenge to effective learning taking place in the classroom. This investigation applied the three themes of constructivism that flow from Social Development theory as the theoretical foundation for the implementation of a multilingual tutorial (MLT) pilot programme as an intervention to improve the performance of the students in the course. The aim of this investigation was to determine whether MLTs could assist the student and lecturer to overcome the challenges that the language barrier presents and improve student performance in the first-year Law course. The MLTs were positively received by the participants and the cohort showed an above average performance in the course. MLTs indeed assisted in improving the performance of the participants. However, these findings are accompanied by the caveat that other factors impacting on student performance have not been excluded.

Keywords: Social Development Theory, multilingual tutorials, More Knowledgeable Other, Zone of Proximal Development, scaffolding

INTRODUCTION

Poor throughput rates and high attrition rates as a result of poor academic performance in Commercial Law for Accountants 1 created a bottleneck that increased the cost of training for repeating students and decreased admissions opportunities for school leavers seeking access to the Accounting programme at the institution where this investigation was conducted. Literature has identified various factors that impact significantly on students' academic performance, namely, students' effort and previous schooling (Siegfried and Fels, 1979; Anderson and Benjamin, 1994), parents' education and family income (Devadoss and Foltz, 1996), self-motivation, age of student and learning preferences (Aripin, Rohaizad,

¹ Date of submission 26 February 2015

Date of acceptance 10 June 2015

Yeop & Anuar, 2003), class attendance (Romer, 1993), and entry qualifications. These factors impact on student performance to varying degrees, depending on, among others, the cultural and institutional context (Mlambo, 2011). This view is supported by Walqui (2006: 159) who states that 'education never takes place in a vacuum but is deeply embedded in a socio cultural milieu'. Geertz defines culture as

an historically transmitted pattern of meanings embodied in symbols, a system of inherited conceptions expressed in symbolic forms by means of which men communicate, perpetuate, and develop their knowledge about and their attitudes toward life (Geertz, 1973d: 89).

Language is one of the various symbol systems that develop through social interaction within a particular culture and the student inherits language as a member of that culture. As a consequence, the background and culture of the student should be taken into consideration throughout the learning process, as they form part of the presage factors (Biggs, 1989) that influence the knowledge and truth that the student constructs, detects and acquires during the learning process (Wertsch, 1997). Vygotsky's Social Development Theory provides a foundation for this view.

There is general consensus that language is fundamental to communication and understanding in the classroom (Benson, 2004). As a consequence, the student's inability to master the language of instruction impacts on his or her cognitive development. Various authors have concluded that proficiency in the language of instruction can affect comprehension of the content and, as a result, student performance (Moschkovich, 2002; Griffin and Jitendra, 2008; Orosco, Swanson, O'Connor and Lussier, 2011). English has gained momentum as the medium of instruction in higher education in non-English speaking countries across the world (Ammon and McConnel, 2002; Coleman, 2006; Costa & Coleman, 2012; Maiworm and Wächter, 2002; Wächter and Maiworm, 2008; Byun, Chu, Kim, Park, Kim & Jung, 2011). The main language of instruction in most education systems across the African continent is English, in spite of the fact that English is not the mother tongue of the majority of students (Crystal, 2003; De Klerk, 2002; Lavoie, 2008). South Africa is no exception. However, many of the students in South Africa emerge from basic education with deeply ingrained and weak interlanguages, which affect their further education at tertiary level (Hatting and Van der Walt, 2007).

Kapp (1998: 28) asserts that 'many lecturers assume that immersion in the discourse of the discipline automatically results in sub-conscious acquisition' of knowledge. She argues that lecturers themselves are so caught up in their respective disciplines that they lose sight of the specific linguistic and cognitive demands that they make on the students. Kapp found that students who are not coping with their second or third language are inclined to 'miss the (often subtle) linguistic cues which are indicative of the culture of the discipline' (Kapp, 1998: 28). Therefore, when Commercial Law for Accountants 1 students who are not proficient in the language of instruction are immersed in the discourse of the discipline of Law, it amounts to a form of submersion schooling, which is defined as schooling in a language which the learner does not speak (Skutnabb-Kangas, 1981). Alidou et al, concluded that

if a switch in the MOI (medium of instruction) occurs before students have developed a high level of written as well as spoken proficiency in both the L1 (first language) and L2 (second language) the learning process across the curriculum is interrupted. Learners will fall behind their peers who have L1 or MTE (mother tongue education) throughout in other education systems (Alidou et al., 2006: 15).

The language of instruction, under these circumstances, becomes a barrier to effective teaching and learning as cognitive learning and language learning are compounded (Benson, 2004) and affects student performance negatively. Various studies have shown that the use of the mother tongue is more effective in the early literacy and content learning stages than a foreign second language (Cummins, 2000; Dutcher,

1995; Laguarda and Woodward, 2013). However, there is a lack of empirical evidence across the African continent in support of the idea that the use of the mother tongue at advanced levels of learning could aid student success (Nyika, 2015). Nevertheless, support for the use of the mother tongue at advanced levels is to be found in research conducted in South Africa and Tanzania (Brock-Utne, 2007).

Therefore, when the Commercial Law 1 lecturer encountered poorly formulated and incoherent responses to questions posed in law examinations, the investigation into the cause thereof focused on a diagnostic assessment of the student's proficiency in the language of instruction and used Social Development Theory as the theoretical foundation for the corrective action.

SOCIAL DEVELOPMENT THEORY

Lev Vygotsky (1896-1934) is regarded as the founder of Social Development Theory which argues that social interaction precedes development and that consciousness and cognition occur as a result of socialisation and social behaviour. The three themes of constructivism that flow from Social Development Theory are, the belief that social interaction plays a fundamental role in the process of cognitive development, and the concepts of the More Knowledgeable Other (MKO) and the Zone of Proximal Development (ZPD).

Social Development Theory formed the foundation for the social constructivist school of thought, which rejects the notion that learning can be separated from its social context. According to Vygotsky:

Every function in the child's cultural development appears twice; first, on the social level and, later on, on the individual level; first between people (interpsychological) and then inside the child (intrapyschological). This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All the higher functions originate as actual relationships between individuals (Vygotsky, 1978: 57).

Vygotsky considered development to be a lifelong process which is preceded by social interaction and argued that social interaction ultimately leads to cognitive development. This implies that individual development cannot be understood without making reference to its underlying social and cultural context.

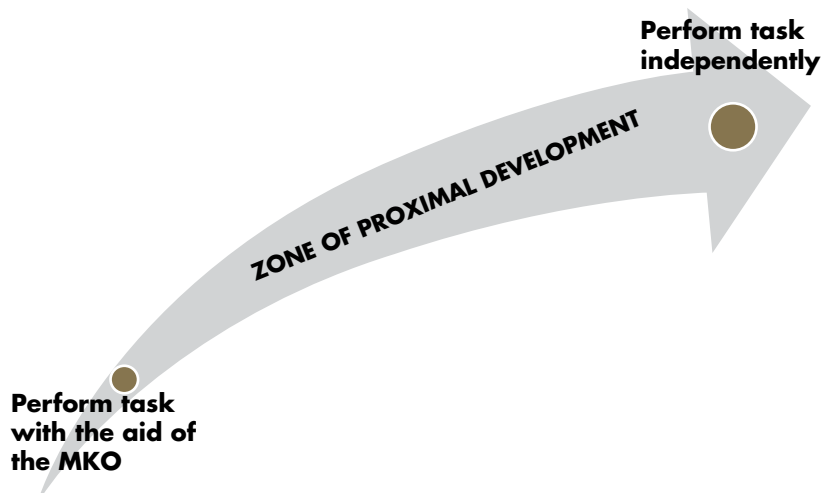
Vygotsky (1962) regarded the moment of convergence between speech and practical activity as the most significant moment in the intellectual development of a human being. This is the moment at which the learner acquires the capacity to comprehend as well as articulate his or her experiences. He claimed that language develops from social interactions initially for communication purposes. However, language ability becomes internalised as thought and inner speech. Language is therefore not only a means through which information is transmitted but it is a powerful tool for intellectual adaptation.

The MKO is described as a person who has a more advanced understanding or is more skilled than the learner. This advanced understanding or skill could relate to a particular task, process or concept. The MKO could be a teacher, a tutor, a peer or, with the advancement of technology, even a computer. The task of the MKO is to assist the learner to reach the stage where he or she can perform the task independently.

Vygotsky (1978) draws a distinction between two developmental levels, the level of actual development and the level of potential development. The level of actual development is the level that the learner has already achieved and the level of potential development (ZPD) is the level that the learner is able to achieve with assistance. He describes the ZPD as 'the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through

problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky 1978: 86). The ZPD therefore refers to the gap between the learner's ability to perform the task with the aid of the MKO and the learner's ability to perform the task independently. Vygotsky argued that learning occurs in this zone. Figure 1 below is an illustration of the ZPD.

Figure 1:
The Zone of Proximal Development



In the wake of Vygotsky's departure, a body of literature emerged that suggests that Vygotsky proposed learning to be a dynamic, interrelated process through which the students become active agents in their learning, while teachers mediated among students' personal meanings, meanings of collective thinking and culturally established meaning (Wells and Chang-Wells, 1992; Ball, 1993; Cobb, Wood & Yackel, 1993; Smagorinsky and O'Donnell-Allen, 2000; Engle and Conant, 2002; Magnussen and Palincsar, 2005; Bain, 2006; Lee, 2007). The focus in this investigation is on the three constructivist themes that emerge from Social Development Theory, its application in higher education and its relevance for MLTs as an intervention to improve student performance in Commercial Law for Accountants 1. This will be discussed in greater detail below.

CULTURE AND INFORMATION SYSTEMS AND TECHNOLOGY

Social Development Theory finds application in higher education, in the form of reciprocal teaching, scaffolding and apprenticeship (Mcleod, 2007). Where the novice and the MKO are engaged in reciprocal teaching, they collaborate by learning and practising four fundamental skills, which are, summarising, questioning, clarifying and predicting (Doolittle, Hicks, Triplett, Nichols, and Young, 2006). The role of the MKO as a scaffold is steadily reduced over time as the skill and understanding of the apprentice improves.

There is a growing body of literature that suggests that instructional scaffolding as a teaching method has become an integral part of higher education (Rosenshine and Meister, 1992; Garrison and Kanuka, 2004; Holton and Clarke, 2006; Yin, Song, Tabata, Ogata, and Hwanga, 2013; Cull and Davis, 2013; Mackiewicz and Thompson, 2014). Wood, Bruner and Ross (1976) first coined the term 'scaffolding' which could be described as actions taken by an 'expert' to improve the performance of a 'novice'. Scaffolding has its foundation in Social Development Theory in the concept of the ZPD. The student entering higher education is considered to be a 'novice' and the 'expert' or MKO could be the lecturer, a tutor, a peer or even a computer programme as mentioned before.

Brush and Saye (2002) distinguishes between hard scaffolding and soft scaffolding. They define hard scaffolding as 'scaffolding that is planned in advance to help students with a learning task that is known in advance to be difficult' (Brush and Saye, 2002: 2). Soft scaffolding, on the other hand, is defined as 'dynamic, situation specific aid' (Brush and Saye, 2002:2). Van Lier (1996) also refers to contingent scaffolding, where the nature and support required is dependent on the needs of the students during the time of instruction. Holton and Clarke (2006) refer to reciprocal scaffolding, which involves two or more students of varying abilities working collaboratively together on a task.

The design of the MLT programme intervention, which is discussed under the heading *Considerations in selecting and implementing the learning tasks* below, took into consideration all of the above forms of scaffolding.

THE CASE FOR MULTILINGUAL TUTORIALS

The MLT programme is an integral part of a broader teaching and learning strategy in Commercial Law for Accountants 1 which has its foundation in Biggs' notion of constructive alignment (Biggs, 1989). The components of this programme were designed to be in dynamic interaction with each other, instead of adopting a linear approach to the alignment of the teaching and learning activities (Leach, 2014). The purpose of the MLT programme was to aid student learning in law through primary language tuition, in other words, it had to be integrated with, and aligned to, the other teaching and learning activities. The goals and objectives for each MLT were aligned to the specific outcomes for each unit in the learner guide and the specific outcomes, in turn, were aligned to the overall goals and critical cross field outcomes of the course (Leach, 2014).

Academic literature has consistently reported the pedagogical advantages of bilingual schooling (Baker, 2006; Cummins, 2000; Benson, 2004). Where familiar language is used to teach beginning literacy, it 'facilitates an understanding of sound-symbol or meaning-symbol correspondence' (Benson, 2004: 3). Other literature has cautioned against the switch in the medium of instruction before students have developed a proficiency in their first and second language (Alidou et al., 2006). In addition, Hatting and van der Walt (2007) reported that many South African students emerge from basic education with weak interlanguages. The use of the mother tongue for the purpose of tutoring is, therefore, supported by academic literature.

The value of tutoring in education is also well documented (Gartner, Kohler and Riessman, 1971; Durling and Schick, 1976; Bargh and Schul, 1980; Webb, 1982; Foot, Shute, Morgan and Barron, 1990; Forman, 1994). These authors have highlighted peer tutoring, in particular, for its inherent verbalisation and questioning. Social interactionists (Vygotsky, 1978; Rogoff, 1990) value tutoring for its use of scaffolding, the MKO and the apprenticeship concept. Lee (1988) reported that peer tutoring in higher education was cost effective and showed up well in relation to retention of students and reducing student dropout.

This study therefore draws upon this authority when it explores the introduction of MLTs as an intervention to enhance student performance in Commercial Law for Accountants 1.

RESEARCH PROCESS

The purpose of the research project was to determine whether the introduction of an MLT programme as an intervention for students who are not proficient in English would improve student performance in Commercial Law for Accountants 1.

The research process entailed the identification of the research design, sample selection, the selection and implementation of learning tasks and collecting and analysing the data (Battacherjee, 2012). Each of these will be discussed in more detail below.

Ethical considerations

The study was conducted with the consent and under the supervision of the institution's Centre for Higher Education Development and the Faculty Language Coordinator. Consent to conduct the study within the programme was obtained from the Head of Department. The informed consent of all the participants in the study was obtained. The MLTs were confined to two of the three regional languages, isiXhosa and Afrikaans, for two reasons. Firstly, the language of instruction is English, and, secondly, limited physical and human resources were directed to where the demand was the greatest. The MLTs were accessible to the entire target population. Participation in the research was voluntary and confidentiality and anonymity were observed.

Considerations in selecting and implementing the learning tasks

The programme was designed to give effect to three themes of constructivism that flow from Social Development Theory. Conditions were therefore created that allowed for the informal, social interaction between peers and tutors (MKOs) in the mother tongue while engaging with the learning material. Students who had Afrikaans and isiXhosa as their mother tongue were separated into different tutorial groups and tutors who were fluent in these languages were assigned to the respective groups.

Time constraints required the application of hard scaffolding (Brush and Saye, 2002) as the experience with previous cohorts highlighted the areas that were regarded as difficult. Hence, a problem-based approach was used. Tutors were also prepared for soft scaffolding (Brush and Saye, 2002), or contingent scaffolding (Van Lier, 1996) as MLT attendance was voluntary and some students did not require MLT support in every aspect of the course. The TAs, therefore, had to be prepared for the ever-changing cohort of students in the MLT.

The problem-based approach and group work in the MLTs also facilitated reciprocal scaffolding (Holton and Clarke, 2006), which is a method that involves a group of two or more collaboratively working together, as students of varying abilities were put together to work together on a task.

The probing questions set in case studies were designed with an increasing degree of difficulty to push students systematically beyond their limitations to ensure that the student progresses from the point where he or she can perform the task with the aid of the MKO, to where the student can perform the task independently. In other words, activities were designed to move the student along the ZPD.

Research design

The investigation is based on action research design. It endeavours to understand a complex social phenomenon, that is, the language barrier to effective teaching and learning, by introducing an intervention in the form of MLTs and observing the effects of the intervention (Battacherjee, 2012).

Selection of the sample

The institutional HEMIS database was used for the purpose of identifying the group from which the target population for the study would be drawn. The criteria used were enrolment as a student for the law course during the year of investigation and mother tongue other than the language of instruction. A voluntary diagnostic test was administered at the beginning of the course for the purpose of identifying the sample frame. All students from the target population were invited to attend the MLTs and attendance was voluntary. A total of 94 students participated in the MLTs of which 85 consented to participating in

the survey. The unit of analysis comprised eight students who have Afrikaans as mother tongue and 86 students who have isiXhosa as mother tongue.

Collecting and analysing the data

The data collection followed a mixed method approach through which both qualitative and quantitative techniques were used before, during, and after the implementation of the MLT programme. The voluntary diagnostic test was administered before the implementation of the MLT programme and, following the implementation of the MLT programme, qualitative data was collected through the observations of independent observers during the MLTs. A student survey was conducted after the participants wrote their final summative assessment in the course. Secondary data was obtained from the Faculty records in the form of the success rate in the subject of the participants in the study. The diagnostic test, observations by independent observers and the survey of student evaluation of the programme will be discussed in greater detail below.

Diagnostic test

The diagnostic test was designed to determine the capacity of the student to read a simplified legal text with comprehension and apply the principles contained in the text to a given set of facts by formulating a written response to a typical application question in a law examination. The test was based on the Canadian Academic English Language Diagnostic Sample Test (CAEL DIAGNOSTIC). The assessment of listening skills was excluded as the delivery in the classroom differs from the traditional lecturing method. A score below 50% in either the reading or the writing component was an indication that MLT support was required.

Observations by independent observers

Independent observers who were fluent in isiXhosa and Afrikaans from the institution's Centre for Higher Education Development observed the MLTs in action and reported their observations in writing to the subject coordinator. This qualitative data was subjected to open coding, linking the texts to the key theoretical concepts in the study, which are, socialisation in the mother tongue, the MKO and the ZPD, as well as the goals and objectives of the programme.

Student evaluation of the programme

Quantitative data on student evaluation of the programme was collected through a survey using a structured questionnaire. The responses to 31 statements were captured using the interval-level response through a five-point Likert scale. The statements were focused on socialisation in the mother tongue, the MKO, the ZPD and the goals and objectives of the programme. The statements relating to the three constructivist themes were randomised across the questionnaire. The results were entered on a spreadsheet and totals, means and averages were calculated.

RESULTS

This paper focuses on the results of the evaluation of the programme by the students, the reports from the independent observers, as well as the success rate of the students in the course and who participated in the MLTs. The results will be reflected under the three constructivist themes which are social interaction as an aid to cognition, the MKO and the ZPD. The results will also address the student performance in the course.

Social interaction aided cognition

Communicating in the mother tongue

Table 1 reflects the responses from students to the statements relating to whether the use of the mother tongue aided their learning. The results show strong support for the use of the mother tongue among the students who participated in the MLT programme.

Table 1:
Communicating in the mother tongue aided student learning

Communicating in the mother tongue	No response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1a: I understood easily what the TA was saying because it was explained in the mother tongue	8.2	49.4	34.1	5.9	1.2	1.2
1c: Difficult material was simplified through the explanation in the mother tongue	7.1	31.8	35.3	17.6	3.5	4.7
1g: TAs could recognise when students failed to understand because they could communicate with students in the mother tongue	7.1	29.4	40.0	17.6	1.2	4.7
1i: Using my mother tongue helped me to participate in the discussion during the tutorial	7.1	49.4	31.8	9.4	1.2	1.2
2d: MLTs encouraged me to express myself	8.2	36	39	14	1.2	1.2
2a: MLTs made learning easy and interesting	7.1	38	44	9.4	1.2	1.2
5c: MLTs enabled me to express myself more effectively in English in the subject as I understood the concepts better	13	33	42	9.4	0	2.4

A majority of students (83.5%) agreed or strongly agreed that they understood what the tutorial assistant was saying because the TA spoke their mother tongue. Very few students (2.4%) disagreed or strongly disagreed with this statement. Most students (67.1%) also agreed that difficult material was simplified through the explanation in the mother tongue. Some opted to remain neutral (17.6%) and a few (8.2%) disagreed with the statement. Most students (69.4%) agreed with the statement that TAs could recognise when students failed to understand because they could communicate with students in the mother tongue. Few students disagreed (5.9%) and some (17.6%) remained neutral. A majority of students (81.2%) also indicated that using their mother tongue aided them in participating in the discussions during the tutorial. A further 75% indicated that that they managed to express themselves more effectively in English in the subject as they understood the concepts better. Most students (75%) also indicated that MLTs encouraged them to express themselves and most (82%) agreed that MLTs made learning easy and interesting.

Independent observers noted that 'the interaction in the tutorial is premised in culture' with isiXhosa speaking students being addressed as '*bhuti*' (brother) and '*sisi*' (sister) and Afrikaans speaking students (male and female) being addressed as 'guys'. They also noted that tutors used a bilingual approach as 'code-switching' occurred between the mother tongue and English during the tutorial.

Student involvement

Table 2 reflects the students' views on their involvement in the MLTs. Their responses are mainly positive.

Table 2:
Student Involvement in the MLTs

Student involvement	No response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1 j: Enough time was allowed for questions and discussions	8.2	35.3	34.1	16.5	4.7	1.2
1 k: Students were encouraged to debate different points of view	9.4	42.4	30.6	11.8	4.7	1.2
2c: Different methods were used during the MLTs to involve me in learning	8.2	28	38	21	3.5	1.2

A majority of students (69.4%) indicated that enough time was allowed for questions and discussions during the MLT with 16.5% remaining neutral. Most students (73%) also agreed that they were encouraged to debate different points of view during the MLT and 83.5% indicated that using the mother tongue helped them to participate in the discussions during the tutorial. Many students (66%) agreed that different methods were used during the MLTs to involve them in learning, with 21% opting to remain neutral.

Independent observers noted that 'tutors negotiate the way to do the tutorial', that a 'relaxed atmosphere' existed in the classroom enabling 'spontaneous participation' and that students were 'having fun with the terminology'.

Influence beyond the MLT

Table 3 reflects student opinion on the influence of MLTs beyond the tutorial sessions. The results show most students were of the opinion that MLTs enabled them to increase their participation during formal lectures. It further shows that most students indicated that it was pivotal to their success in the subject and therefore recommended the MLTs.

Table 3:
Influence of MLT beyond the tutorial

Influence beyond the MLT	No response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
7a: MLTs helped me to ask relevant questions during formal lectures	14	36	34	12	1.2	2.4
7b: MLTs helped me to offer my point of view during formal lectures	14	36	33	14	0	2.4
7c: Frequent attendance at MLTs was essential to my success in the subject	14	31	45	8.2	0	2.4
7d: MLTs have been a great benefit to me	13	41	35	7.1	1.2	2.4
7e: I highly recommend MLTs	13	49	29	4.7	1.2	2.4

Most students (70%) indicated that MLTs helped them to ask relevant questions during formal lectures and 69% also agreed that MLTs helped them to offer their point of view during formal lectures. A majority

(76%) indicated that frequent attendance at MLTs was essential to their success in the subject and found it to be a great benefit to their learning. Most students (78%) strongly recommended the MLTs.

More Knowledgeable Other

Table 4 contains the results of student responses to statements related to the MKO. The results show that the majority of students found TAs to be knowledgeable and effective.

Table 4:
Effectiveness of the MKO

Effectiveness of TAs	No response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1b: TAs showed a clear understanding of the course topics	7.1	42.4	36.5	11.8	2.4	0.0
1d: TAs had an effective style of presentation	9.4	18.8	44.7	23.5	3.5	0.0
1e: TAs were well-prepared for the tutorial session	9.4	30.6	38.8	15.3	4.7	1.2
1f: TAs were well-organised in presenting the tutorials	8.2	27.1	41.2	18.8	2.4	2.4
1h: TAs were helpful when students had problems	7.1	44.7	37.6	8.2	1.2	1.2
1l: Team teaching was used effectively in MLTs	9.4	28.2	40.0	18.8	2.4	1.2
3c: TAs made good use of examples and illustrations	7.1	38	38	15	1.2	1.2
4a: In MLTs sensitivity to individual abilities was shown	14	24	40	18	2.4	2.4
4b: Sessions with individual TAs as well as joint sessions (team teaching) helped me to learn better	13	28	44	12	1.2	2.4

Most students (78.9%) agreed that TAs showed a clear understanding of the course topics. Many students (63.5%) found the TAs to have an effective style of presentation, 69.4% agreed that TAs were well-prepared for the tutorial sessions, 68.3% agreed that they were well-organised in presenting the tutorials and 68.2% indicated that team teaching was used effectively in the MLTs. Most students (82.3%) also indicated that TAs were helpful when students had problems and a majority (76%) agreed that TAs made good use of examples and illustrations. Most students (64%) further agreed that tutors showed sensitivity to individual abilities and 72% agreed that the joint sessions as well as the individual sessions with tutors helped them to learn better.

Independent observers found the TAs to be 'competent', as 'tutors used reciprocal teaching' while they continued 'probing and making students unpack legal concepts'. They also observed that tutors continued to 'rephrase (legal concepts) in the mother tongue' where necessary.

They found that the TAs 'kept focus on the learning process' and were 'well-prepared'. Independent observers further indicated that TAs would 'take charge where discipline is lacking' and had 'at times, a no nonsense approach'. They found TAs to be 'mature, yet (able to) present at a level to which their charges (could) relate'.

Zone of Proximal Development

The results from the diagnostic test showed that all the participants in the MLTs scored 50% and below in the test. This was an indication of the actual level of the participants. However, the responses from the

students and the independent observers, as well as the success rate of the participants in the MLTs suggest that students were indeed moved along the ZPD.

Responses from the students and independent observers

Table 5 contains the results of statements related to the ZPD. The results show that the majority of students responded positively to statements.

Table 5:
MLTs aided deeper learning

Relationships, concepts and skills	No response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
2b: MLTs made me feel challenged and motivated	7.1	33	49	8.2	2.4	0
3a: MLTs helped me to apply theory and to solve problems	8.2	42	38	9.4	1.2	1.2
5b: MLTs enabled me to perform at my best in the subject	13	36	35	12	1.2	2.4
3b: MLTs effectively blended facts with theory (principles)	9.4	38	34	16	1.2	1.2
5d: I can use the information/skills I learned in MLTs in other subjects in the programme	13	34	41	7.1	2.4	2.4

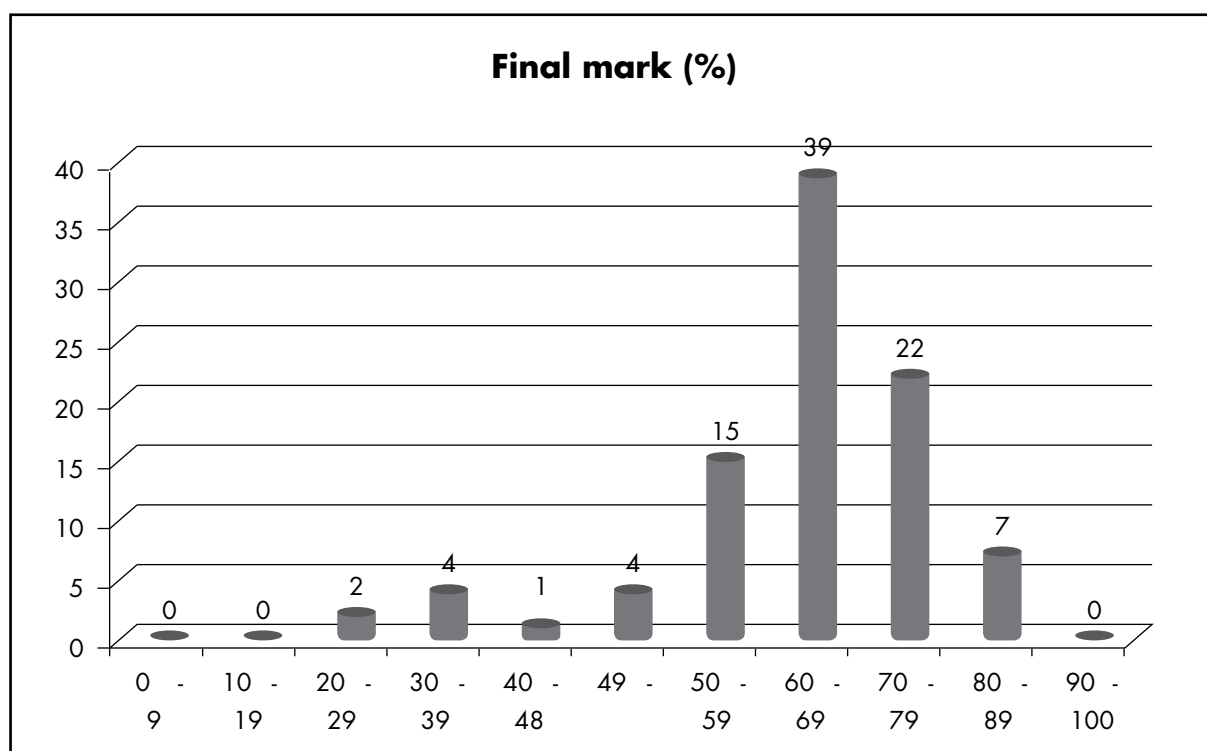
A majority of students (82%) agreed that MLTs made them feel challenged and motivated and most students (80%) agreed that MLTs helped them to apply theory and solve problems. Many (72%) indicated that facts were effectively blended with theory in the MLTs and most students (76%) indicated that TAs made good use of examples and illustrations. Most students (71%) also agreed that MLTs helped them to perform at their best in the subject and that most of them (75%) would be able to use the skills and information they have learned in the MLTs in other subjects in the programme.

The independent observers found that 'Tutors probed beyond the surface meaning, students asked questions/sought clarity/validated their understanding with own examples'. They observed that 'key concepts were clarified using the mother tongue to enhance understanding'. Independent observers found that the 'problem-based approach (in the tutorials) encouraged deep learning'.

Student performance in the subject

Figure 2 reflects the performance in the subject of the total number of students ($n = 94$) who attended the MLTs. The results show 83% of the participants in the study were successful in the course and 17% were unsuccessful. The high pass rate of the cohort is further supported by the quality of the passes that was obtained. The symbol distribution shows that the performance of the students in the sample was above average. Most of the participants (68%) scored 60% and above. Of the students who were unsuccessful, 36% scored 49%, 1% short of the required 50%. A further 30% of the unsuccessful candidates did not write the first summative assessment which contributed 15% towards their final mark.

Figure 2:
Final results of participants



DISCUSSION

The results from the student survey, the independent observers as well as the student performance in the subject show that the MLTs aided student learning in the law course. The discussion of the results will follow the constructivist themes identified above.

Socialisation aids cognition

MLTs, through socialisation in the mother tongue, enabled students to become active agents in their own learning as language no longer presented a barrier to student participation. The code-switching between the mother tongue and the language of instruction enabled students to participate in the discussions while engaging with the learning material. Using the mother tongue further encouraged students to express themselves not only during the MLTs but also during formal lectures. The use of the mother tongue enabled TAs to recognise when students were not grasping the concepts as the language of instruction was eliminated as a factor that impacted on student cognition. The fact that most students indicated that they understood what the TA was saying because of the use of the mother tongue is evidence that learning (comprehension) was not postponed until the student became more competent in the language of instruction. This is further supported by the fact that most students claimed that difficult material was simplified through the use of the mother tongue and that MLTs made learning easy and interesting.

The relaxed and familiar atmosphere, created by the TAs, who were regarded as peers, brought about a level of spontaneity to the extent that students could have fun while learning. This is in contrast with the formality of the lectures. This confirms the assertion by Kapp (1998) that tutorials are the best place to introduce multilingualism.

The reports by the independent observers which noted that 'the interaction in the tutorial is premised in culture' lends support to the notion that individual development cannot be understood without making

reference to its embedded social and cultural context. When isiXhosa speaking students were addressed as 'bhuti' (brother) and 'sisi' (sister), it was a reflection of a form of address that is deeply embedded in the Xhosa culture. Likewise, the TA addressed the males and females attending the Afrikaans tutorial collectively as 'guys', which is an informal form of address particularly prevalent among the youth.

All of the above, together with the fact that students validated their understanding of the concepts using their own frame of reference, lends support to Vygotsky's argument that consciousness and cognition are end products of socialisation and social behaviour. It further confirms that learning cannot be separated from its social context. These social interactions enabled the students to be truly integrated into the knowledge community.

The More Knowledgeable Other (MKO)

The importance of the MKO is highlighted by the evaluation of the students as well as the independent observers. The competence of the TAs is reflected in the positive response by students to statements related to their effectiveness. TAs were found to have a clear understanding of the course topics and an effective style of presentation. Most students also found the TAs to be well prepared, well organised and helpful.

The competence of the TAs is demonstrated by their capacity to engage in contingent scaffolding as they 'negotiated their way to do the tutorial'. They nevertheless did not lose sight of hard scaffolding as they kept their focus on the learning process. TAs managed to make students active participants in their own learning by making time for questions and discussions and encouraging them to debate different points of view. Their capacity to use team teaching effectively is further evidence of their use of scaffolding within the MLT.

The Zone of Proximal Development

The problem-based approach encouraged deep learning as the evidence shows that TAs probed beyond surface meaning, encouraging students beyond their existing capacity. Students asked questions, sought clarity and validated their understanding with their own examples, using their own frame of reference. The fact that most students felt that key concepts were clarified using their mother tongue to enhance understanding shows that the use of the mother tongue unlocked student participation in the MLTs and became a vehicle through which the student could move along the ZPD. TAs continued to probe, making students unpack the concepts as they rephrased the concepts in the mother tongue.

Further evidence that students were moved along the ZPD is found in the fact that students indicated that MLTs were essential to their success in the subject, that it helped them to ask relevant questions and offer their opinion during formal lectures which were conducted in English.

The student success rate in the subject is further evidence of this movement along the ZPD for the majority of participants. The high success rate in the subject (83%) by this cohort and the quality of the pass (68% scoring above 60%) that most of the participants have obtained, are an indication that the MLTs have influenced student performance in the subject.

CONCLUSION

This study shows that the introduction of the MLT programme has improved the academic performance of the participants in Commercial Law for Accountants 1. The positive response to the MLTs by students, the positive evaluation of the MLT programme by the independent observers and the above average performance of most of the participants in the MLT programme, support Vygotsky's argument that language is not only a means through which information is transmitted but it is a powerful tool for intellectual adaptation. There is clear evidence in support of the view that socialisation in the mother tongue aids

cognition. Furthermore, the emphasis by participants and observers alike on the competence of the MKO, highlights the importance of the role of the 'expert' in assisting the 'novice' along the ZPD. Strong support for the MLTs by participants as an intervention to improve student performance, combined with the above average performance in the subject, show that MLTs enabled the student to progress along the ZPD. This study did not eliminate other factors that impact on student performance, namely, students' effort, previous schooling, parents' education, family income, self-motivation, age of the student, learning preferences, class attendance and entry qualifications. These conclusions are therefore accompanied by the caveat that these factors that may have impacted positively on the cognitive development and performance of the cohort have not been excluded in this study and warrants further investigation.

REFERENCES

- Alidou, H., Boly, A., Brock-Utne, B., Dialo, Y.S., Heugh, K. & Wolff, H. (2006) *Optimising Learning and Education in Africa – The Language Factor*. Working document for the Association for the Development of Education in Africa. http://www.adeanet.org/adeaPortal/adea/downloadcenter/Ouga/B3_1_MTBLE_en.pdf (Accessed 3 February 2014).
- Ammon, U. and McConnell, G. (2002) *English as an academic language in Europe: A survey of its use in teaching*. Bern: Peter Lang.
- Anderson G. and Benjamin D. (1994) 'The determinants of success in university introductory courses' *Journal of Economic Education* 25(2) pp.99-119.
- Aripin, M., Rohaizad, R., Yeop, U. and Anuar, M. (2003) 'Students' learning styles and academic performance' 22nd Malaysia Forum 15 July 2008, Kuala Lumpur Convention Centre. Kuala Lumpur, Malaysia.
- Baker, C. (2006) *Foundations of Bilingual Education and Bilingualism*. (4th ed.) Clevedon: Multilingual Matters.
- Bain, R.B. (2006) 'Rounding Up Unusual Suspects: Facing the Authority Hidden in the History Classroom' *Teachers College Record* 108(10) pp.2080-2114.
- Ball, D.L. (1993) 'With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics' *Elementary School Journal* 93 pp.373-397.
- Bargh, J.A. and Schul, Y. (1980) 'On the cognitive benefits of teaching' *Journal of Educational Psychology* 72(5) pp.593-604.
- Battacherjee, A. (2012) *Social Science Research: Principles, Methods, and Practices*. [Online] (2nd ed.) Creative Commons Attribution – Non Commercial ShareAlike 3.0. http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1002&context=oa_textbooks (Accessed 2 May 2013).
- Benson, C. (2004) 'The importance of mother tongue-based schooling for educational policy' Paper commissioned for the *EFA Global Monitoring Report 2005, The Quality Imperative*. UNESCO: Paris.
- Biggs, J.B. (1989) 'Approaches to enhancement of tertiary teaching' *Higher Education Research and Development* 8 pp.7-25.
- Brock-Utne, B. (2007) 'Language of instruction and student performance: New insights from research in Tanzania and South Africa' *International Review of Education* 53 pp.509-530.

- Brush, T.A. and Saye, J.W. (2002) 'A Summary of Research Exploring Hard and Soft Scaffolding for Teachers and Students Using a Multimedia Supported Learning Environment' *The Journal for Interactive Online Learning* 1(2) pp.1-12.
- Byun, K., Chu, H., Kim, M., Park, I., Kim, S. & Jung, J. (2011) 'English-medium teaching in Korean higher education: Policy debates and reality' *Higher Education* 62 pp.431-449.
- Cobb P., Wood T., and Yackel, E. (1993) 'Discourse, mathematical thinking, and classroom practice' In E.A. Forman, N. Minich and C.A. Stone (Eds.) *Contexts for Learning*. New York: Oxford University Press.
- Coleman, J.A. (2006) 'English-medium teaching in European higher education' *Language Teaching* 39 pp.1-14.
- Costa, F., Coleman, J.A. and Bialystok, E. (2012) 'A survey of English-medium instruction in Italian higher education' *International Journal of Bilingual Education and Bilingualism* 2012 pp.1-17.
- Crystal D. (2003) *English as a global language*. Cambridge, UK: Cambridge University Press.
- Cull, M. and Davis, G. (2013) 'Students' Perceptions of a Scaffolded Approach to Learning Financial Planning: An Empirical Study' *Accounting Education* 22(2) pp.125-146.
- Cummins, J. (2000) *Language, power and pedagogy: Bilingual children in the crossfire*. Clevedon: Multilingual Matters.
- De Klerk, V. (2002) 'Language issues in our schools: Whose voice counts?' *Perspective Education* 20 pp.1-28.
- Devadoss, S. and Foltz, J. (1996) 'Evaluation of factors influencing students' attendance and performance' *American Journal of Agricultural Economics* 78(3) pp.499-507.
- Doolittle, P.E., Hicks, D., Triplett, C.F., Nichols, W.D. and Young C.A. (2006) 'Reciprocal Teaching for Reading Comprehension in Higher Education: A Strategy for Fostering the Deeper Understanding of Texts' *International Journal of Teaching and Learning in Higher Education* 17(2) pp.106-118.
- Durling, R. and Schick, C. (1976) 'Concept attainment by pairs and individuals as a function of vocalization' *Journal of Educational Psychology* 68(1) pp.83-91.
- Dutcher, N. (1995) 'The use of first and second languages in education. A review of international experience' *Pacific Island Discussion Paper Series No.1*. Washington DC: The World Bank. http://www-wds.worldbank.org/servlet/WDSContentServer/IW3P/IB/2000/02/24/000094946_99031910564840/Rendered/PDF/multi_page.pdf (Accessed 20 April 2015).
- Engle, R.A. and Conant, R.R. (2002) 'Guiding Principles for Fostering Productive Disciplinary Engagement: Explaining and Emergent Argument in a Community of Learners Classroom' *Cognition and Instruction* 20 pp.399-484.
- Foot, H.C., Shute, R.H., Morgan, M.J. and Barron, A. (1990) 'Theoretical issues in peer tutoring' In H.C. Foot, M.J. Morgan, and R.H. Shute (Eds.) *Children Helping Children*. London and New York: John Wiley.

- Forman, E. (1994) 'Peer collaboration as situated activity; examples from research on scientific problem solving' In H.C. Foot, C.J. Howe, A. Anderson, A.K. Tolmie and D.A. Wardes (Eds.) *Group and Interactive Learning*. South Hampton and Boston: Computational Mechanics.
- Garrison, D.R. and Kanuka, H. (2004) 'Blended learning: Uncovering its transformative potential in higher education' *Internet and Higher Education* 7 pp.95-105.
- Gartner, S., Kohler, M. and Riessman, F. (1971) *Children Teach Children: Learning by Teaching*. New York: Harper and Row.
- Geertz, C. (1973d) 'Religion as a Cultural System' *The Interpretation of Cultures*. New York: Basic Books.
- Griffin, C. and Jitendra, A.K. (2008) 'Word problem-solving instruction in inclusive third-grade mathematics classrooms' *Journal of Educational Research* 102 pp.187-201.
- Hatting, K. and Van der Walt, J.L. (2007) 'Fluency and accuracy in Grade 12 ESL learners' *Journal Per Linguam A Journal of Language Learning* 23(2) pp.15-28.
- Holton, D. and Clark, D. (2006) 'Scaffolding and metacognition' *International Journal of Mathematical Education in Science and Technology* 37 pp.127-143.
- Kapp, R. (1998) 'Language, Culture and Politics The case of Multilingualism in Tutorials' In S. Angèlil-Carter (Ed.) *Access to Success. Literacy in academic context*. Cape Town, South Africa: University of Cape Town Press (Pty) Ltd.
- Laguarda A.L. and Woodward, W.P. (2013) 'They own this: Mother tongue instruction for indigenous Kuku children in Southern Sudan' *School Psychology International* 34(4) pp.453-469.
- Lavoie, F. (2008) "'Hey teacher, speak black please": The educational effectiveness of bilingual education in Burkina Faso' *International Journal Bilingual* 11 pp.661-667.
- Lee, R.E. (1988) 'Assessing retention program holding power effectiveness across smaller community colleges' *Journal of College Student Development* 29(3) pp.255-262.
- Lee, C.D. (2007) *Culture, literacy, and learning: Blooming in the midst of the whirlwind*. New York: Teachers College Press.
- Leach, N. (2014) 'Formative computer-based assessment to enhance teaching and learning' *South African Journal of Higher Education* 28(3) pp.1033-1046.
- Mackiewicz, J. and Thompson, I. (2014) 'Instruction, Cognitive Scaffolding, and Motivational Scaffolding in Writing Center Tutoring' *Journal Composition Studies* 42(1) pp.54-78.
- Magnusson, S.J. and Palincsar, A.S. (2005) 'Teaching to promote the development of scientific knowledge and reasoning about light at the elementary school level' In J. Bransford and S. Donovan (Eds.) *How students learn: History, mathematics, and science in the classroom*. Washington, DC: National Academies Press.
- Maiworm, F. and Wächter, B. (2002) *English-language-taught degree programmes in European higher education*. Bonn: Lemmens.

- Moschkovich J. (2002) 'A situated and sociocultural perspective on bilingual mathematics learners' *Math Think Learn* 4 pp.189-212.
- McLeod, S.A. (2007) Vygotsky – Simply Psychology <http://www.simplypsychology.org/vygotsky> (Accessed 11 November 2013).
- Mlambo, V. (2011) 'An analysis of some factors affecting student performance in an introductory course at the University of West Indies' *Caribbean Teaching Scholar* 1(2) pp.79-92.
- Nyika, A. (2015) 'Mother tongue as the medium of instruction at developing country universities in a global context' *South African Journal of Science* <http://dx.doi.org/10.17159/sajs.2015/2015/20140005> (Accessed 25 June 2015).
- Orosco, M.J., Swanson, H.L., O'Connor, R. and Lussier, C. (2011) 'The effects of dynamic strategic math on English language learner' word problem solving' *Journal of Special Education* 47(2) pp.96-107.
- Rogoff, B. (1990) *Apprenticeship in Thinking; Cognitive Development in Social Context*. Oxford and New York: Oxford University Press.
- Romer, D. (1993) 'Do students go to class? Should they?' *Journal of Economic Perspectives* 7(3) pp.167-174.
- Rosenshine, B. and Meister, C. (1992) 'The Use of Scaffolds for Teaching Higher-Level Cognitive Strategies' *Journal Educational Leadership* 49(7) pp.26-33.
- Smagorinsky, P. and O'Donnell Allen, C. (2000) 'Idiocultural diversity in small groups: The role of the relational framework in collaborative learning' In C.D. Lee and P. Smagorinsky (Eds.) *Vygotskian perspectives on literacy research: Constructing meaning through collaborative inquiry*. New York: Cambridge University Press.
- Siegfried, J. and Fels, R. (1979) 'Research on teaching college economics: A survey' *Journal of Economic Literature* 17(3) pp.923-939.
- Skutnabb-Kangas, T. (1981) *Bilingualism or Not: The Education of Minorities*. Clevedon: Multilingual Matters.
- Vygotsky, Lev.S. (1962 [1934]) *Thought and language*. Cambridge, MA: MIT Press.
- Vygotsky, Lev. S. (1978) *Mind and society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.
- Van Lier, Leo. (1996) *Interaction in the Language Curriculum: Awareness, Autonomy and Authenticity*. Harlow: Longman.
- Wächter, B. and Maiworm, F. (2008) *English-taught programmes in European higher education. The picture in 2007*. Bonn: Lemmens.
- Walqui, A. (2006) 'Scaffolding Instruction for English Language Learners: A Conceptual Framework' *The International Journal of Bilingual Education and Bilingualism* 9(2) pp.159-180.
- Webb, N.M. (1982) 'Peer interaction and learning in co-operative small groups' *Journal of Educational Psychology* 5(74) pp.642-655.

Wells, G. and Chang-Wells, G.L. (1992) *Constructing knowledge together*. Portsmouth, NH: Heinemann.

Wertsch, J.V. (1997) *Vygotsky and the formation of the mind*. Cambridge, Massachusetts: Harvard University Press.

Wood, D.J., Bruner, J.S. and Ross, G. (1976) 'The role of tutoring in problem solving' *Journal of Child Psychiatry and Psychology* 17(2) pp.89-100.

Yin, C., Song, Y., Tabata, Y., Ogata, H. and Hwang, G.J. (2013) 'Developing and Implementing a Framework of Participatory Simulation for Mobile Learning using Scaffolding' *Educational Technology and Society* 16(3) pp.137-150.

The notion of Lego® Mindstorms as a powerful pedagogical tool: Scaffolding learners through computational thinking and computer programming^{1 2 3}

Jacqui Chetty, University of Johannesburg, South Africa

ABSTRACT

This paper documents a study that was conducted with regard to the use of robotics as an innovative pedagogical tool for computer programming. The robotics in question relate to the Lego Mindstorms robots that were introduced as a means to further develop learners' problem-solving skills and motivate learners to have fun while learning. Vygotsky's philosophy regarding the Zone of Proximal Development supports the notion of Lego Mindstorms robots as a pedagogical tool. A mixed methods study was conducted and the aim of the project was twofold. Firstly, to determine whether robots reinforce fundamental computer programming concepts that were taught in the classroom environment. Secondly, to determine whether robots provide motivation and interest in computer programming. The issues regarding the pedagogical approach are discussed and feedback from learners is analysed. The results are positive and encouraging.

Keywords: Pedagogy, Lego Mindstorms robots, Computer programming

INTRODUCTION

Learners enrolled for a computer programming course for the first time often find it challenging to understand the fundamental concepts surrounding the discipline. Equally, educators find it difficult to teach such learners. Research indicates that traditional pedagogical approaches do not lend themselves towards a positive experience for both learner and educator (Lister, 2011). Given that pedagogical approaches are a powerful determinant as to whether a learner will be successful in a course, it is worthwhile investigating the variety of pedagogies and related tools available to determine whether there is an approach that could adequately scaffold learners studying computer programming courses. Research indicates that using games as a pedagogical tool to teach learners the art of algorithmic problem solving as well as programming has successfully been implemented to scaffold learners.

1 Date of submission 10 February 2015
Date of acceptance 3 June 2015

2 The financial assistance of the National Research Foundation (NRF) in South Africa under Grant number 84244 is hereby acknowledged. Any opinion, findings and conclusions or recommendations expressed in this material are those of the authors and the NRF does not accept any liability thereto.

3 The assistance of Dr E.C. Anderssen, who was responsible for the classroom facilitation, the management thereof, and support of the Lego Mindstorms study is also hereby acknowledged.

The idea of using games to teaching fundamental computer programming concepts is not new (Lawhead et al., 2002). Using games as a learning tool is advocated as games have the potential to positively contribute to successful learning (Piteira & Haddad, 2011). Lego Mindstorms robots is one such game that provides an innovative teaching tool for building learners' computer programming skills. Amongst others, the game provides two necessary elements for learning, namely understanding and motivation (Piteira & Haddad, 2011). It provides a platform for learners to build, reinforce and practise fundamental computer programming concepts, while adding an element of fun. Lego Mindstorms scaffolds learners' learning because it uses action instead of explanation; accommodates a variety of learning styles and skills; reinforces mastery skills; provides an opportunity to practise; and affords an interactive, decision-making context.

Lego Mindstorms robots may prove to be an effective teaching tool to *scaffold* learners as they refine the art of computational thinking and learn to design complex algorithms. Pedagogical approaches are still the most powerful predictor of how successful or unsuccessful learners can be (deRaadt, 2008). This is particularly true of teaching approaches that focus on the notion of 'scaffolding'. The scaffolding becomes an instrument for educators to 'bridge' learners who are navigating a new discipline as they clasp frantically to fragile knowledge in their minds. Structured scaffolding that is maintained for a reasonable period of time allows the fragile knowledge to solidify and become entrenched in the mind of the learner.

The paper is structured as follows: firstly, a review of literature is presented and includes the difficulties that learners face when learning to program; the pedagogical approaches for computer programming; and the use of Lego Mindstorms robots as a pedagogical tool. Secondly, the methodological approach used is described. Thirdly, the results are presented and discussed, and finally the limitations as well as the conclusion are presented.

LITERATURE REVIEW

Difficulties faced by learners

The skills expected for computer programming are complex and learners worldwide find it very difficult to solve problems (Mead et al., 2006). The problem arises from learners needing to articulate a problem into a programming solution (Lahtinen, Ala-Mutka & Jarvinen, 2005; Garner, Hadden & Robins, 2005) by combining syntax and semantics into a valid program (Winslow, 1996) through the construction of mechanisms and explanations (Soloway, 1986). In order to achieve this, learners need to be able to apply fundamental computer programming concepts (Robins, Rountree & Rountree, 2003; Garner et al., 2005) and understand abstract concepts (Lahtinen et al., 2005). When learners are faced with trying to absorb and understand too many new concepts at one time, their working memory may become overloaded. Their overloaded working memories make it very difficult for them to understand the concepts taught to them. The idea of working memory and load capacity is also known as cognitive load theory (Mason, Cooper, Simon & Wilks, 2015).

Cognitive load. Humans are limited to a working memory capacity that is strictly bounded and relatively small (Mason et al., 2015). This means that due to our limited working memory capacity our memories can become overloaded and our cognitive performance can decline. This is particularly true when novice learners are faced with the fundamentals associated with computer programming concepts as these concepts are fraught with abstract ideas or higher order thinking skills. Such concepts are often layered, one on top of the other, before a learner is able to design and construct computer programs. Given that such learners are new to the discipline (novices) their cognitive load increases exponentially, often exceeding their critical threshold level of cognitive capacity (Mason et al., 2015).

Given this scenario, it is therefore not unexpected for research to indicate that the results linked to computer programming courses aimed at novices more often than not have a particularly high failure rate. The situation in South Africa is worse as many learners in South Africa often do not acquire a sound education at primary and secondary educational level (Jansen, 2012). This means that when such learners are presented with a subject, such as computer programming at tertiary level, they struggle as their cognitive load is pushed to capacity. These learners often cannot adapt as they are expected to learn concepts that require abstract reasoning, also known as computational thinking (Bower & Falkner, 2015).

Computational thinking

Computational thinking (DBR_Collective) can be defined as the ability of a learner to develop problem-solving strategies and techniques that assist in the design and use of algorithms and models (Falkner, 2015). According to Lister (2011) such thinking needs time to develop. In fact, most learners possess limited computational thinking (CT) in the early stages of their lives, but such skills should develop and mature, given that learners are educated and receive formal training (Lister, 2011). Given the importance of CT, Kramer (2007) asks whether it is possible to improve learners' CT at tertiary level. He also advocates that unless learners' CT is well developed, they should not be allowed admission into computing courses. Given the South African context, Kramer's advice cannot be implemented, as the nation has a social responsibility to encourage education amongst previously disadvantaged learners. Nelson Mandela felt very strongly about this and insisted that learners have the right to tertiary education (Jansen, 2012). Therefore, innovative pedagogical approaches as well as tools that support learning and favour the development of CT must be investigated. Lego Mindstorms is one such tool that is investigated in this study.

The next section explores the different pedagogical approaches used for computer programming.

PEDAGOGICAL APPROACHES TO COMPUTER PROGRAMMING

Pedagogical approaches relate to the manner in which teaching and learning takes place in order to facilitate desired learning outcomes (Pears et al., 2009). There are many pedagogical approaches to teaching and learning (Boyer, Langevin & Gaspar, 2008; Pears et al., 2009). For example, the teacher-centric approach consists of activities, such as lecturing, questioning and demonstration. The lecturer is the expert who transfers their knowledge across to learners (Xiaohui, 2006). This approach is used extensively to teach not only computer programming courses, but also other disciplines of study. Although the teacher-centric approach is the most popular approach, there are other pedagogical approaches that are unique to teaching and learning computer programming. For example, the learner-centred pedagogical approach involves philosophies that have been around for many decades and even a century. These include social constructivism, peer-led learning, collaborative learning and problem-based learning, to name a few.

Regardless of the pedagogical approach used in the classroom, learning computer programming can take on many forms. Firstly, teaching a particular language, such as Java, where the structure, syntax and semantics of the programming language itself is taught (Pears et al., 2009). Most textbooks are structured according to the constructs of a particular programming language. For example, learners may learn how to make use of variables by applying the eight primitive data types known to Java.

Secondly, teaching problem-solving techniques applicable to computer programming is another approach. The idea is that if a learner is able to solve one type of problem, that learners should be able to solve other problems of a similar nature (Pears et al., 2009; Winslow, 1996). Very precise computer programming structures are taught within this context. For example, instead of learning how to make use of variables by applying the eight primitive data types known to Java, variables can be learned by learners developing pseudo code or flowcharts.

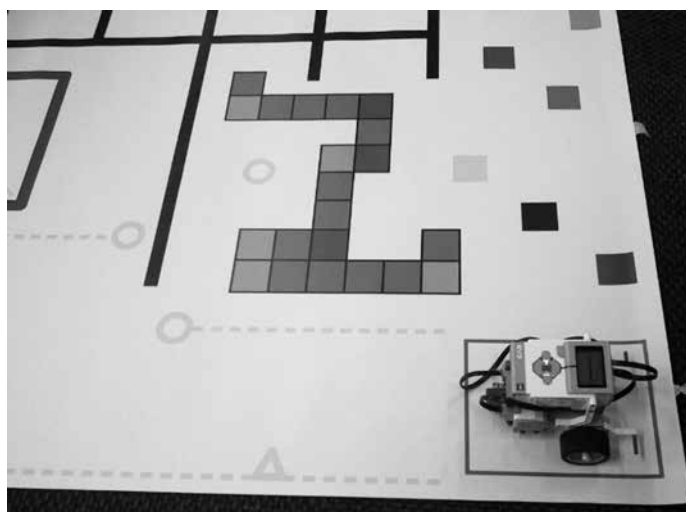
Thirdly, teaching programming through the introduction of graphical user interface (Guillory) tools, such as Scratch, Greenfoot or Alice provide a simulated computer programming environment that is user-friendly. It provides ease-of-use when trying to develop computer programs (Maloney, Resnick, Rusk, Silverman & Eastmond, 2010).

Lastly in this paper, teaching learners how to read, trace and debug existing programs (Patton, 2004; Miliszewska & Tan, 2007) before they embark on writing their own programs is also very effective. Tracing a computer program reveals underlying concepts to learners that they most probably would not have thought of themselves. Learners then learn to mimic these revolutionary ideas and make them their own.

Lego Mindstorms as a pedagogical tool. Lego Mindstorms robots have become a popular pedagogical tool to teach and learn introductory computer programming concepts (Lui, Ng, Cheung & Gurung, 2010; Lawhead et al., 2002). The emphasis is on the word 'tool', where robots create a rich environment that provides a platform for novices as well as experienced teachers to implement a laboratory experience for students to learn programming skills in an interesting, unique and challenging manner. In effect, Stein (1998) challenges the computer science teaching community to move from the premise that computation is calculation to the notion of computation is interaction. Robots would be a natural way to explore such a concept.

Lego Mindstorms robots form part of Lego education and can be bought through a representative responsible for retailing such toys. As illustrated in Figure 1, the Mindstorms consist of building components, a programmable brick, active sensors and motors. There is software for which both Graphical User Interface (GUI) and command line interfaces are available. The robots, together with their associated interfaces provide an opportunity for educators to transform classrooms into rich laboratory or software studios, where learners can experience learner-centred learning, collaborative learning and peer-to-peer programming experimentation (Yamazaki, Sakamoto, Honda, Washizaki & Fukazawa, 2015). This environment provides an opportunity for learners to 'put their programming skills to the test' as what they program comes to life through the Lego Mindstorms robot. They can visually understand 'what works', 'what does not work' and 'why'.

*Figure 1:
An EV3 Lego Mindstorms robot*



Lego Mindstorms robots provide an opportunity for learners to understand fundamental computer programming concepts that are, by their very nature, abstract (deRaadt, 2008). These concepts are not analogies with the real world (Piteira & Haddad, 2011) and learners find it challenging to relate to real-world problems. Moreover, traditional pedagogical approaches to teaching computer programming exacerbate this problem (Rountree, Rountree & Robins, 2002).

Introducing Lego Mindstorms robots provides a unique opportunity to transform a classroom environment in which (Piteira & Haddad, 2011): learners are given an opportunity to 'grapple' with real-world problems; the Lego Mindstorms robot becomes a learning tool that can scaffold learners; fragile knowledge of abstract programming concepts can be reinforced; and learners are given an opportunity to experiment, explore and enjoy programming. These aspects can create a degree of motivation.

The motivation factor

Research indicates that emotions, such as hope, anger, relief, anxiety and boredom are significantly related to motivation, learning strategies, cognitive resources, self-regulation, and academic achievement, as well as personality and classroom antecedents (Pekrun, Goetz, Titz & Perry, 2002). According to Jenkins & Davy (2002) motivation in particular is a crucial component related to learners' success. Although motivation is difficult to quantify, Jenkins has identified expectancy and value as two factors, which when multiplied can predict learners' motivation (Jenkins, 2001). Expectancy is related to the extent to which learners feel that they are able to succeed. Value is related to what they expect to gain. For example, confident learners who feel that they are able to succeed will attach a value or goal related to high marks. They will most likely score high in the area of motivation as: $\text{motivation} = \text{expectancy} * \text{value}$ (Jenkins, 2001).

A motivated learner would therefore experience emotions related to hope, enjoyment and pride, whereas an unmotivated learner would experience emotions related to anger, frustration, anxiety and boredom. Lego Mindstorms robots provide an opportunity for learners to experiment and explore. The idea of learning-through-play is an effective tool to create personal motivation and satisfaction of learning (Piteira & Haddad, 2011).

METHODS AND MATERIALS

The research methodology approach adopted was a Design-based research (DBR_Collective) approach, which included two iterative cycles of testing. Although much data has been collected using this approach, the article focuses on two sets of data collection, namely qualitative as well as quantitative data, aimed at answering the following questions that relate to the aims and objectives of Lego Mindstorms robots: firstly, did the learners indicate that the robot programming further improved their partially developed fundamental computer programming concepts? Secondly, are learners more motivated to become computer programmers due to their exposure to Lego Mindstorms robots?

The qualitative study focused on collecting data by means of a focus group interview. The aim of the interview was to identify the extent to which the Lego Mindstorms robots assisted learners in improving their fundamental computer programming skills as well as to identify whether learners felt that the robots introduced an element of fun and motivation. The data was analysed using Atlas.Ti and a number of codes, categories and themes were established. The themes were expanded upon to provide guidelines for educators wanting to make use of Lego Mindstorms robots as a learning tool to improve problem-solving skills amongst learners.

Additionally, the study made use of a quantitative analysis, where learners answered closed-ended types of questions from a questionnaire developed by the researcher. The questions also focused on the aims and objectives of the article. A Likert-type scale was included with scores, from Strongly Disagree (1) to

Strongly Agree (4). These scores, means and standard deviations calculated statistical data aimed at answering the research questions.

A rich collection of both qualitative as well as quantitative data emerged. Both sets of results indicate that Lego Mindstorms robots provide a platform on which learners' fragile computer programming knowledge can be improved upon using a language independent tool that captures the persistent truths about problem solving and programming techniques.

This article is an extension of a conference paper written by the researcher (Chetty, 2015) and it differs from the conference paper in that the themes that have been developed from the qualitative analysis have been expanded upon for educational practice. Furthermore, the article presents a set of quantitative results pertaining to learners' opinions regarding Lego Mindstorms robots being a tool that can be used to teach generic programming skills. The quantitative analysis surveyed a larger number of learners.

Participants

Of the 135 learners enrolled for a computer programming module 56 learners participated in a Lego Mindstorms project that focused on improving their problem-solving skills as well as to determine whether Lego Mindstorms robots provide the motivation needed to learn a difficult task, such as computer programming. The participants worked collaboratively every week for two hours (within a six month semester), under the supervision of a facilitator as well as each group being led by a tutor.

Course content

The Lego Mindstorms course included explanations regarding the various components; instructions for building a standard EV3 robot; guidelines to program the robot to perform the basic tasks; and exercises for practising. Each session included suggestions for learners to explore further. Figure 2 illustrates the learning in action.

*Figure 2:
Demonstration in action*



The learners were tasked to complete a variety of activities aimed at:

- building the Lego Mindstorms robot according to specifications
- introducing the Lego Mindstorms robot from a physical perspective as well as from a software-driven perspective

- providing learners with a simple task that required them to learn about movement (rotations, power, angles, timing), where the task was to program the robot to move in the shape of a square
- providing learners with more complex tasks within the movement learning area, where learners needed to change their programs and include looping
- introducing learners to the colour sensor, which would require them to make use of looping, such as move until...
- introducing learners to the touch and ultra sound sensor, which would allow them to program the robots regarding distance and object avoidance
- providing a variety of tasks every week to simulate the above mentioned robots concepts that reflect the programming environment
- introducing a theme, such as the solar system where learners were asked to program the robots to move from 'earth' to the 'moon' and the robot had to avoid any 'alien spaceships'.

DATA COLLECTION TECHNIQUES

As discussed, this study comprised both qualitative and quantitative data collection techniques. Firstly, a focus group interview was a suitable approach to enrich the evaluation of the pedagogical design as it allows a particular case to be examined to provide insight into the extent to which learners felt that the pedagogical intervention increased their knowledge and supported their learning regarding the module (Denzin & Lincoln, 1994). Focus group interviews capture the complexities of a phenomenon; such detailed observations can very rarely be captured in surveys or experimental designs (Falkner, Vivian & Falkner, 2014; Hartley, 2004). Although the sample size is small, the number of participants in the study being 21, it is sufficient for qualitative research that ranges from 1 to 99, with an average sample size of 22 (Troskie-de Bruin, 2013). The focus group interview was conducted and recorded by the researcher. Its aim was to gather data regarding the research questions presented above in this article.

Secondly, a questionnaire was constructed that contained Likert-type items to measure students' extent of agreement with each item on a scale ranging from Strongly Disagree to Strongly Agree. Using SPSS v.22, measures of central tendency were computed to summarise the data of each item. Measures of dispersion were computed to understand the variability of responses for each item. Items with low reliability scores (Cronbach alpha <.70) were excluded from the computation. Care was taken to reverse code items where applicable.

RESULTS

Qualitative results

The audio recording was transcribed to text and the data were subjected to the process of open coding and axial coding. The qualitative software ATLAS.ti was used (Troskie-de Bruin, 2013) to code the units as well as derive specific categories. A first-cycle coding was conducted using the Initial Coding (open coding) method as it allows the researcher to 'code quickly and spontaneously, pay meticulous attention to the rich dynamics of data through line-by-line coding – a "microanalysis" of the corpus' so that the researcher can 'search for processes – participant actions that have antecedents, causes, consequences and a sense of temporality' (Saldana, 2013; Strauss & Corbin, 1990). This type of coding was chosen as the researcher wanted to determine learners' experiences regarding the use of Lego Mindstorms robots to improve problem solving as well as to determine whether the robots provide an element of motivation for learners. A number of codes were identified as the data was searched sentence-by-sentence.

As the code list was quite extensive Morse (1994: 25) advises to reorganise and reanalyse data to 'link seemingly unrelated facts logically, of fitting categories one with another'. During the second cycle of coding, 'axial coding' was conducted. Boeije (2010) explains that the purpose of axial coding is 'to

determine which [codes] in the research are the dominant ones and which are the less important ones ... [and to] reorganise the data set: synonyms are crossed out, redundant codes are removed and the best representative codes are selected' (Boeije, 2010: 109). Saldana (2013) succinctly explains that the 'axis' of Axial Coding is a category(ies) that is (are) derived from First Cycle coding. Table 2 tabulates the development of categories from the codes. These categories were further sub-divided into themes, namely solving real-world authentic activities, computational thinking, collaborative learning, and motivating learners through Lego Mindstorms.

*Table 1:
Classification of categories*

Category	Frequency	Frequency %
Improve problem-solving skills	21	100%
Testing programming abilities using real-world problems	5	23.8%
Fun way to develop programming skills	21	100%
Collaboration with peers	21	100%
Computational thinking	11	52.4%
Motivation factor	10	47.6%
Made new friends	7	33.3%

Additionally, learners were also asked to indicate by way of a 'Yes' or 'No' whether the Lego Mindstorms robots provided scaffolding, given their fragile knowledge related to computer programming concepts learned in the classroom environment. As seen in Table 2 all learners indicated that the robots provided an opportunity to further reinforce problem-solving skills. Of the 21 learners, 20 learners felt that the robot programming provided them with an opportunity to learn how to break a problem into smaller steps.

*Table 2:
Responses regarding Mindstorms reinforcing learning*

Programming concept	'yes'	'no'
Problem solving	21	
Breaking problems into small steps	20	1
Practise algorithmic skills	20	1
Assist in understanding how to solve problems better algorithmically	21	
Assist in coding programs that require input-processing-output	19	2
Assist in coding programs that require methods	21	
Assist in coding programs that require repetition	21	

Table 2 shows a classification of the codes that were generated using Atlas Ti. As discussed, during the axial coding process the codes that best represented and supported the notion of Lego Mindstorms robots being beneficial to improve programming skills were highlighted and grouped into themes. The main themes that emerged related to solving real-world authentic activities, computational thinking, collaborative learning, and motivation. Each is now discussed.

Solving real-world authentic activities

Researchers and experts worldwide agree that an authentic learning activity represents a problem that has real-world relevance, is ill-defined, and needs to be completed over a period of time (Herrington, 2013; Lombardi, 2007; Herrington, 2006; Brannock, Lutz & Napier, 2013).

Real-world relevance relates to problems that match 'every day' tasks of professionals in practice. Such problems are normally 'messy' or ill-defined. Ill-defined problems are problems that when described to learners are open to interpretation, as opposed to problems that are developed by following step-by-step solutions. Instead of being highly prescriptive, ill-defined problems provide an opportunity for learners to identify the steps needed to complete the activity (Herrington, Reeves & Oliver 2006). As ill-defined problems are more complex, learners need a longer period of time to complete such activities. A longer time period allows learners to reflect on the choices they make regarding the solution. This enhances their metacognitive skills (Lombardi, 2007).

Learners in particular embraced and acknowledged the idea of using the Lego Mindstorms robots to program in the real-world. For example, learners were asked to develop a 'car' using their robot. The car had to be able to navigate from point A to point B, while avoiding obstacles and adhering to traffic robots (red – stop; green – go). As learners understood the real-world problem in the context of their own lives, this made it easier for them to develop and implement the coding instructions. Some of the responses from learners included the following responses, where the bolded responses highlight the themes:

- Yes I enjoyed it because of the observation of **using concepts of programming logic in physical situations**
- It's a fun programming logic, whereby you can solve problems in different ways through that robot. It is realistic, **because you can just imagine the robot in real-life situations**

Another learner acknowledged the notion of using the Lego Mindstorms robot to benchmark his personal programming skills.

- Yes, I really did. When I joined the project I was curious and I wanted **to test my abilities** by trying and taking an opportunity that was presented to us. I am glad I did because now I know where I stand and I know I can

Asking learners to solve problems that involved authentic tasks that they could relate to, provided essential scaffolding so that the gap between 'understanding the problem' and determining 'how to solve it' was not too wide.

Computational thinking

Vygotsky (1978) suggested this as any higher order thinking skill (including computer programming skills) evolves in the construction of joint social activities (collaborative tasks), prior to developing into skills that can be applied to independent problem solving (Beck & Chizhik, 2013). The social spaces or 'zones of proximal development' are critical if higher order thinking skills are to be achieved (Vygotsky, 1978).

For many of the learners at the university, critical thinking and deeper level learning is difficult to achieve. However, the learners acknowledged the notion of critical thinking when learning how to program the robots.

- It challenged our thinking and encouraged us to **make use of critical problem-solving skills** to accomplish our tasks

- It was different from the usual work we do in the labs. It provided the platform to test what we learnt in class – **it tested our analytical skills**

Collaborative learning

The idea of constructing knowledge through a social setting can be a powerful educational and learning tool (Vygotsky, 1978; Kozulin et al., 2003; Stetsenko, 2010; Ben-Ari, 1998). This type of learning involves two important concepts, namely social constructivism and collaboration. Social constructivism is a philosophy and a learning theory that has established itself in the last few decades (Karagiorgi & Symeou, 2005). It attempts to take the individual into account by viewing them as unique, having their own personal and subjective experiences (Karagiorgi & Symeou, 2005). The individual imposes meaning on the world by constructing knowledge based on past experiences, goals, curiosities and beliefs (Cole, 1992). In this way, the individual adapts and constructs knowledge as they make sense of their world.

It is widely acknowledged that there are many educational advantages that can be derived from learners working in collaboration with one another (Brown, 2005; Preston, 2006). The expression 'I learn what I believe as I hear myself speak' is very powerful. One advantage is that learners are more successful when learning occurs in the midst of others. Learners learn from one another as they discuss problems and formulate solutions (Ben-Ari, 1998; Lombardi, 2007).

Collaborative learning is one of the most powerful characteristics of Lego Mindstorms. Learners remark:

- I made new friends who **helped me on my programming skills** and now I can take shortcuts to make the best out of programming
- I was a person who liked to isolate herself but **now I can't even count how many friends I have**, so it boosted my social life
- We were discussing and **bringing our knowledge into one**

Collaboration with others is a powerful pedagogical tool. Such collaboration often leads to increased motivation among learners.

Motivating learners and Lego Mindstorms robots

Hirumi & Kebritchi (2008) argue that games are effective tools for learning because, amongst other advantages, games create personal motivation and satisfaction. One of the main advantages of using games, such as Lego Mindstorms to motivate learners, is due to the inherent characteristics associated with the games, namely energy, direction, persistence and equifinality – all aspects that stimulate and motivate learners (Serrano-Camara, Paredes-Velasco, Alcover & Velezques-Iturbide, 2014).

Motivation forms part of a conceptual model or framework known as the self-determination theory. This theory emphasises the importance of the development of internal human resources for personal development and self-regulation. Such self-determination refers to something because it is interesting or enjoyable, such as the Lego Mindstorms. Such games provide a natural wellspring of learning and achievements that can either be encouraged or discouraged by facilitators' practices. Such motivation results in high quality learning and creativity (Ryan & Deci, 2000).

The Lego Mindstorms robots inspired and motivated learners to think about programming in a very real way. They reported:

- Because **now I want to program bigger** and better robots

- **It motivates me** because it showed me that what I am studying is relevant to today
- Better programmer, **makes me want to perfect the robot** and make it do exactly what I want it to do

Quantitative results

Table 3:
Results of Lego Mindstorms robots promoting learning

Question	N	M	MODE	SD
Q1 The use of Lego Mindstorms robots helped me to write better problem-solving solutions	56	3.09	3.00	.794
Q2 I found better problem-solving solutions after playing with Lego Mindstorms robots.	56	3.07	3.00	.815
Q3 The more I 'played' with the Lego Mindstorms robots the better my problem-solving solutions became.	56	3.03	3.00	.844
Q4 I understood if / else (selection) better after using Lego Mindstorms	56	3.23	3.00	.572
Q5 I understood looping (repetition) better after using Lego Mindstorms	56	3.30	3.00	.570
Q6 I understood programming better after using Lego Mindstorms	56	3.28	3.00	.564
Scale	56	3.17	3.00	.693

It is immediately apparent from Table 3 that students either Agreed (3) or Strongly Agree (4) with each item, as the mean of all the responses is above 3 Agreed (3). Items 1 ($n = 56$, $M = 3.09$, $SD = .794$) and 2 ($n = 56$, $M = 3.07$, $SD = .815$) indicate that learners made use of Lego Mindstorms robots to learn problem-solving skills and that they enjoyed the use of the tools. Items 2 and 3 show that learners 'use of the Lego Mindstorms robots helped me to write better problem-solving solutions'. Table 3 also indicates that the Lego Mindstorms robots promoted learning. Most of the students either Agreed (3) or Strongly Agree (4) indicated by items 4 ($n = 56$, $M = 3.23$, $SD = .572$), 5 ($n = 56$, $M = 3.30$, $SD = .570$) and 6 ($n = 56$, $M = 3.28$, $SD = .564$) that after completing the Lego Mindstorms project their problem-solving skills had improved.

DISCUSSION

The research questions related to this article focused on two aspects, namely, did learners feel that Lego Mindstorms robots improved fragile knowledge; and were the learners motivated to learn programming due to the interaction with the Lego Mindstorms robots? These questions are now answered as part of a discussion, based on the qualitative as well as the quantitative data presented earlier in the paper.

Firstly, learners indicated that the idea of learning programming using authentic activities proved successful, as they were often able to relate to the real-world problems that they were expected to solve. They felt as if they were real-life programmers. The authentic activities were fun, which motivated them to keep trying.

Secondly, learners felt that the tasks challenged their thinking and it was expected of them to reason in a critical manner, where knowledge had to be transferred from one context to another. As higher order

thinking skills (HOTS) forms an important aspect of learning, one in which lifelong learning skills are formed, the development of programs through robotics assisted in the development of HOTS.

Thirdly, the notion of constructing knowledge in collaboration with one another is one of the most powerful learning tools. Learners constructed solutions in groups where ideas were discussed, a number of solutions were formulated and explained and learners shared their knowledge socially. Learners learned from one another, sometimes they were the ones teaching and other times they were the ones learning.

Lastly, motivation cannot be underestimated within the educational process. Learners who are motivated often achieve more than learners who are not. The learners were very excited to be part of the class every week and an element of competitiveness began to develop from one week to the next. As an educator it could clearly be seen that learners were enjoying the learning experience. The experience of being part of the class motivated learners to develop better solutions that were more and more powerful as the weeks progressed.

LIMITATIONS OF THE STUDY

Providing learners with necessary scaffolding as they learn is essential. As discussed, there are many benefits for both the educator and the learner. However, many lessons were learned from this study. As Lego Mindstorms robots will be fully integrated into the computer programming course from 2015, it is beneficial to reflect on the limitations of making use of Lego Mindstorms robots. While some limitations may be overcome, as the educators become more experienced, other limitations remain as challenges, either to be conquered or not. The limitations of the study include:

- sufficient time available for learners to take full advantage of learning through robots
- a suitable software lab that encourages play
- sufficient time to learn and prepare for the robot lessons
- limited expert knowledge regarding the use of robotics
- support for the use of robots at management level.

Most of these challenges have been overcome to the extent that a further seven sets of Lego Mindstorms robots have been purchased. Additional time has been scheduled on learners' timetables (semester A) and the robots will form part of the computer programming course, where marks will be allocated towards each project. Most importantly, educators have been given the opportunity to register for an official course through UNISA. This will mean that educators have the expertise to extend learners.

CONCLUSION

In the analysis, a variety of categories related to whether Lego Mindstorms robots provided a platform that reinforces fragile computer programming concepts, were identified. Additionally, a quantitative analysis provided further evidence suggesting that learners confirmed that Lego Mindstorms robots assisted them with learning computer programming concepts. Although not a pedagogy within its own right, Lego Mindstorms robots can be a platform that provided an opportunity for the focus of learning to shift from traditional learning, to learning that engages learners actively, using real-world problems. It can allow learner to develop dynamic programming skills in a language independent environment, thus seen as a pedagogical tool. In today's rapidly changing world, providing innovative ways to scaffold learners and challenge them to think in other ways is essential.

As this project was a pilot study, future work will focus on an additional Lego Mindstorms project, where robotics is integrated into the computer programming course presented to first-year learners (novices).

Additionally, the Lego Mindstorms robots course will be presented to Grade 4 learners at a school close to the university where the study was conducted. The focus will be on girls in Information Technology as well as the development of problem-solving skills at a younger level. Lastly, the course will also be presented to student teachers at a university overseas.

REFERENCES

- Beck, L. & Chizhik, A. (2013) 'Cooperative Learning Instructional Methods for CS1: Design, Implementation, and Evaluation' *ACM Transactions On Computing Education* 13(21) pp.470-474.
- Ben-Ari, M. (1998) 'Constructivism in Computer Science Education' Paper presented at the SIGSCE'98 Conference. Atlanta GA USA: ACM.
- Bower, M. & Falkner, K. (2015) 'Computational Thinking, the Notional Machine, Pre-service Teachers, and Research Opportunities' In *Australasian Computer Education (ACE) Conference*, edited by Daryl D'Souza and Katrina Falkner. Sydney, Australia: Australasian Computer Society Inc.
- Boyer, N.R., Langevin, S. & Gaspar, A. (2008) 'Self Direction & Constructivism in Programming Education' *SIGITE'08*. Cincinnati, Ohio, USA: ACM.
- Brannock, E., Lutz, R. & Napier, N. (2013) 'Integrating Authentic Learning into a Software Development Course: An Experience Report' In *SIGITE'13*. Orlando, Florida, USA: ACM.
- Brown, J.S. (2005) 'New Learning Environments for the 21st Century' Forum for the Future of Higher Education Aspen Symposium.
- Chetty, J. (2015) 'Lego Mindstorms: Merely a Toy or a Powerful Pedagogical Tool for Learning Computer Programming' Australian Computer Science Conference (ACSC) 2015. Sydney, Australia.
- Cole, P. (1992) 'Constructivism revisited: A search for common ground' *Educational Technology* 33(34) pp.27-34.
- DBR_Collective. (2003) 'Design-based research: An emerging paradigm for educational inquiry' *Educational Researcher* 32(4) pp.5-8.
- Denzin, N.K. & Lincoln, Y.S. (1994) *Introduction: Entering the field of qualitative research*. Thousand Oaks: Sage.
- deRaadt, M. (2008) 'Teaching Programming Strategies Explicitly to Novice Programmers' University of Southern Brisbane, Queensland, Australia.
- Falkner, K., Vivian, R. & Falkner, N.J.G. (2014) 'Identifying Computer Science Self-Regulated Learning Strategies' *ITiCSE'14*. 19th Annual Conference on Innovation and Technology in Computer Science. Uppsala, Sweden: ACM.
- Falkner, K. (2015) 'Teaching Computational Thinking in K-6: The CSER Digital Technologies MOOC' *Australasian Computer Education (ACE) Conference*. Sydney, Australia: Australia Computer Society Inc.
- Garner, S., Haden, P. & Robins, A. (2005) 'My Program is Correct But it Doesn't Run: A Preliminary Investigation of Novice Programmers' Problems' *Australasian Computing Education Conference*. Newcastle, Australia: Australian Computer Society, Inc.

Guillory, B.A. (2011) 'Teaching through problem solving' <http://www.slideshare.net/bbieniemy/teaching-through-problem-solving1> (Accessed February 2014).

Hartley, J. (2004) 'Case Study Research' in C. Cassell & G. Symon (Eds.) *Essential Guide To Qualitative Methods In Organisational Research*. London: SAGE.

Herrington, J. (2006) 'Authentic e-learning in higher education: Design principles for authentic learning environments and tasks' AACE '10. Vancouver, Canada.

Herrington, J. (2013) 'Its the task that matters most' http://authenticlearning.ino/AuthenticLearning/Authentic_Task.html (Accessed November 2013).

Herrington, J., Reeves, T.C. & Oliver, R. (2006) 'Authentic Tasks Online: A synergy among learner, task and technology' *Distance Education* 27(15) pp.1-15.

Hirumi, A. & Kebritchi, M. (2008) 'Examining the Pedagogical Foundations of Modern Educational Computer Games' *Computers & Education* 51 pp.1729-1743.

Jansen, J. (2012) 'I would seriously consider not sending my child to school in SA' *Moneyweb* <http://www.moneyweb.co.za/mw/view/mw/en/page292681?oid=562851&sn=2009> Detail. (Accessed 24 February 2012).

Jenkins, T. (2001) 'Teaching Programming - A Journey From Teacher To Motivator' *2nd Annual LTSN-ICS Conference*. London: LTSN Centre for Information and Computer Sciences.

Jenkins, T. & Davy, J. (2002) 'Diversity and Motivation in Introductory Programming' *Innovation in Teaching and Learning in Information and Computer Sciences* 1(1) doi: 10.1120/ital.2002.01010003

Karagiorgi, Y. & Symeou, L. (2005) 'Translating Constructivism into Instructional Design: Potential and Limitations' *Educational Technology & Society* 8(11) pp.117-127.

Kozulin, A., Gindis, B., Ageyev, Vladimir S., Miller & Suzanne M. (Eds.) (2003) *Vygotsky's Educational Theory in Cultural Context*. Cambridge: Harvard University Press.

Kramer, J. (2007) *Magazine Communication of the ACM* 50(4) pp.36-42.

Lahtinen, E., Ala-Mutka, K. & Jarvinen, H. (2005) 'A Study of the Difficulties of Novice Programmers' *ITiCSE '05*. Monte de Caparica, Portugal: ACM.

Lawhead, P.B., Bland, C.G., Barnes, D.J., Duncan, M.E., Goldweber, M., Hollingsworth, R.G. & Schep, M. (2002) *A Road Map for Teaching Introductory Programming Using LEGO Mindstorms Robots*. New York USA: ITiCSE-WSR.

Lister, R. (2011) 'Concrete and Other Neo-Piagetian Forms of Reasoning in the Novice Programmer' *Australasian Computer Education Conference*. Perth, Australia: Australia Computing Society Inc.

Lombardi, M.M. (2007) 'Authentic Learning for the 21st Century: An Overview' *Educause* pp.1-12.

Lui, A.K., Ng, S.C., Cheung, H.Y. & Gurung, P. (2010) 'Facilitating Independent Learning with Lego Mindstorms Robots' *acmlnroads* 1(5) pp.49-53.

- Maloney, J., Resnick, M., Rusk, N., Silverman, B. & Eastmond, E. (2010) 'The Scratch Programming Language Environment' *ACM Transactions On Computing Education* 10 Article 16 pp.1-15.
- Mason, R., Cooper, G., Simon & Wilks, B. (2015) 'Using Cognitive Load Theory to select an Environment for Teaching Mobile Apps Development' *Australasian Computer Education (ACE)*. Sydney, Australia: Australia Computing Society Inc.
- Mead, J., Gray, S., Hamer, J., James, R., Sorva, J., St.Clair, C. & Thomas, L. (2006) 'A Cognitive Approach to Identifying Measurable Milestones for Programming Skill Acquisition' *ITiCSE'06*. Bologna, Italy: ACM.
- Miliszewska, I. & Tan, G. (2007) 'Befriending Computer Programming: A Proposed Approach to Teaching Introductory Programming' *Issues in Information Science and Information Technology* 4(13) pp.277-289.
- Pallant, J. (2007) *SPSS Survival Manual. A step-by-Step Guide to Data Analysis Using SPSS for Windows (Version 15)* Milton Keynes: Open University Press.
- Patton, Peter C. (2004) 'New Methods for Teaching Programming Languages to both Engineering and Computer Science Students' http://www.micsymposium.org/mics_2004/Patton.pdf (Accessed January 2014).
- Pears, A., Seidman, S., Malmi, L., Mannila, L., Adams, E., Bennedsen, J., Devlin, M. & Paterson, J. (2009) 'A Survey of Literature on the Teaching of Introductory Programming' 39(4) *ITiCSE-WGR '07* pp.204-223.
- Pekrun, R., Goetz, T., Titz, W. & Perry, R.P. (2002) 'Academic Emotions in Students' Self-Regulated Learning and Achievement: A Program of Qualitative and Quantitative Research' *Educational Psychologist* 37 pp.91-105.
- Piteira, M. & Haddad, S.R. (2011) 'Innovate in Your Program Computer Class: An approach based on a serious game' *OSDOC'11*. Lisbon, Portugal.
- Preston, D. (2006) 'Using Collaborative Learning Research to Enhance Pair Programming Pedagogy' *ACM SIGITE* 3 pp.16-21.
- Robins, A., Rountree, J. & Rountree, N. (2003) 'Learning And Teaching Programming: A Review and Discussion' *Computer Science Educational Journal* 13 pp.137-172.
- Rountree, N., Rountree, J. & Robins, A. (2002) 'Predictors of Success and Failure in a CS1 Course' *ACM SIGCSE Bulletin* 34(4) pp.189-196.
- Ryan, R.M. & Deci, E.L. (2000) 'Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions' *Contemporary Educational Psychology* 25 pp.54-67.
- Saldana, J. (2013) *The Coding Manual for Qualitative Researchers*. LA, London, New Delhi, Singapore: SAGE.
- Serrano-Camara, L.M., Paredes-Velasco, M., Alcover, C. & Velazquez-Iturbide, J.A. (2014) 'An evaluation of students' motivation in computer-supported collaborative learning of programming concepts' *Computers in Human Behaviour* 31 pp.499-508.

Soloway, E. (1986) 'Learning to Program = Learning to Construct Mechanisms and Explanations' *Communications of the ACM* 29(9) pp.850-858.

Stein, L. (1998) 'What We've Swept Under the Rug: Radically Rethinking CS1' *Computer Science Education* 8(2) pp.118-129.

Stetsenko, A. (2010) 'Teaching-learning and development as activist projects of historical Becoming: expanding Vygotsky's approach to pedagogy' *Pedagogies: An International Journal* 5 pp.6-16.

Strauss, A.L. & Corbin, J.M. (1990) *Basics of Qualitative Research: Grounded Theory Procedures and Techniques*. London: SAGE.

Troskie-de Bruin, C. (2013) 'Qualitative research: Requirements for post-graduate study projects' edited by Research and Development Consultants (ASEV). Stellenbosch, South Africa.

Vygotsky, L. (1978) *Mind and Society*. Cambridge, MA: Harvard University Press.

Winslow, L.E. (1996) 'Programming Pedagogy – A Psychological Overview', *SIGCSE Bulletin* 28(6) pp.17-22.

Xiaohui, Hu. (2006) 'Improving teaching in Computer Programming by adopting student-centered learning strategies' *The China Papers* pp.46-51.

Yamazaki, S., Sakamoto, K., Honda, K., Washizaki, H. & Fukazawa, Y. (2015) 'Comparative Study on Programmable Robots as Programming Educational Tools' *Australasian Computer Education (ACE) Conference*. Sydney, Australia: Australia Computer Society Inc.

Stimulating and maintaining students' interest in Computer Science using the hackathon model¹

Jabu Mtsweni, Council of Scientific and Industrial Research (CSIR) & University of South Africa, South Africa
Hanifa Abdullah, University of South Africa, South Africa

ABSTRACT

Computer Science (CS) enrolments at higher education institutions across the globe remain low in comparison to other disciplines. The low interest in CS is often attributed to students' misconceptions about the discipline, such as CS being construed as complex, asocial, and only for computer wizards. Consequently, hackathons, which are self-organised programmes that bring together different stakeholders to collaborate in rapidly building software prototypes, are emerging as one potential solution to address some of the students' misconceptions about the CS field. Using an exploratory case study and activity theory for data analysis; this research article presents substantive research findings that posit hackathons as an approach that could stimulate and maintain students' interest in CS. The key elements of the hackathon model are collaborations, networking, mentoring, hands-on engagement in socially-relevant computing projects, and community involvement. The model was evaluated using expert reviews in terms of its relevance, impact, complexity, and sustainability.

Keywords: Computer Science, Hackathons, Open Distance Learning, Socially Relevant Computing, Community Engagement

1. INTRODUCTION

There is a general concern that the number of students who opt to study Science, Engineering, Technology, and Mathematics (STEM) is low across the globe. In South Africa, for instance, various reports suggest that interest in maths and science amongst learners has dropped by 20% over the recent years (Firth, 2014). The World Economic Forum report suggests that the quality of maths and science education in South Africa is amongst the lowest when compared to other countries (World Economic Forum, 2012). Earlier studies also suggest that between genders, Computer Science (CS) as a discipline is not well represented across the globe (i.e. there is a low number of female students pursuing CS) (Anderson, Lankshear, Timms, & Courtney, 2008; Hill, Corbett & St. Rose, 2009; Papastergiou, 2008).

A number of reasons for the low interest in CS have been studied, some of them including teaching and learning strategies, social relevance of CS, and student awareness and understanding of computing courses (Buckley, Nordlinger, & Subramanian, 2008a; Galpin & Sanders, 2007; Mtsweni & Abdullah,

¹ Date of submission 13 February 2015

Date of acceptance 30 June 2015

2013; Papastergiou, 2008). According to Buckley (2009), the low CS enrolments at higher education institutions could be attributed to the notion that CS is not offered by educators as an idea that is socially relevant, important and caring. It is further postulated that real world problems are lacking in undergraduate computing disciplines, thereby, making CS not a priority alternative for undergraduate students, especially those who are altruistic and socially aware (Buckley, Nordlinger, & Subramanian, 2008b; Hecht & Werner, 2014).

At Open Distance Learning (ODL) institutions, such as the University of South Africa (UNISA), enrolment statistics with regards to interest in CS courses are not so different to traditional universities (Galpin & Sanders, 2007; University of South Africa, 2014). However, ODL universities are unique, especially because of the mode of instruction and delivery; which is complicated by the notion of anytime, anywhere, equitable, flexible and open access (University of South Africa, 2014). Students at such institutions are bound at some point to consider the misconceptions that computing courses are tedious and asocial, since they have limited opportunities to engage directly with their lecturers and communities in practical projects that offer real-world experiences and engaging challenges (Abdullah & Mtsweni, 2013).

It is therefore imperative that research-oriented solutions are put forth in order to tackle the challenges that affect students' interest in CS. The solutions to such challenges are essential for purposes of averting the negative economic, brain drain, political, pedagogical, and social impacts that such low interest in computing discipline could have in our communities at large. In South Africa, it has also been noted that low enrolments and completion of qualifications in computing courses is even leading to IT skills shortage in the business environment (Firth, 2014).

As a result, a number of strategies are being sought by researchers to stimulate interest in the CS discipline, including initiatives such as Socially Relevant Computing (Buckley et al., 2008b; Hecht & Werner, 2014; Richard & Kafai, 2015), which have their own challenges when it comes to being implemented in an ODL environment (Mtsweni & Abdullah, 2013). Conversely, hackathons (Wiggins, Gurzick, Goggins, & Butler, 2014), which are extensively discussed in the background section of this article, are also emerging as a potential solution to the identified problem. However, thus far, no extensive research has been done to investigate their relevance and potential in changing the perceptions and addressing low interest in CS amongst students at higher learning institutions. This article attempts to contribute by addressing some of these research gaps by following an exploratory case study approach conducted over a period of 36 months within a community engagement project at an ODL institution.

The remainder of this article is structured as follows. Section 2 provides background information relating to Socially Relevant Computing (SRC), the current ODL environment, and the concept of hackathons and hacking culture. Section 3 highlights the research aims and research methodology employed for the research presented in this article. Section 4 describes the Computing Pro Bono project, which was the basis of the case study. In Section 5, the results of the case study are discussed. Section 6 presents and describes the hackathon model and its implication in stimulating students' interest in computing disciplines. Section 7 concludes the research by highlighting the essential findings and further research work.

2. BACKGROUND

This section provides background information on the core concepts that underpin the research study, namely Socially Relevant Computing (SRC), Open Distance Learning (ODL), particularly in relation to Computer Science (CS), hacking culture, and hackathons. The concepts are not directly interconnected, but to some extent related. SRC is included in the background, since it has similar aspects (e.g. social aspect) found in the hackathon model, albeit not enjoying the same traction as hackathons across the globe (Briscoe & Mulligan, 2014). In turn, the hacking culture is practised in most hackathons and SRC

projects. Lastly, ODL is discussed in this background section as an alternative environment where the hackathon approach could be implemented for stimulating students' interest in CS. These concepts were mainly derived through rigorous document analyses and participant observations during the case study.

Socially Relevant Computing

To address the importance of incorporating real-world experience in CS, Buckley et al. (2008b), introduced the concept of Socially Relevant Computing (SRC). This is an approach, whereby students are presented with problems of societal and interpersonal relevance, the emphasis being on learning computing for a cause. The central idea is to entice students who ordinarily may not see CS as an alternative to social sciences and the humanities (Pauca & Guy, 2012).

However, SRC requires a different approach to CS instruction ranging from problem representation and modelling, addressing the key concepts of CS (Buckley et al. 2008b). According to Buckley et al. (2008b), SRC is purported to enable students to learn about new domains, work effectively in teams as well as evaluate the social or ethical aspects of their solutions. This is very important because students should in addition to possessing technical skills also be able to assess the societal impact of their work, commit to standards of professional ethics and obtain the life skills necessary to undertake on-going professional development and maintain interest in their discipline. Adding a social relevance dimension to the CS curriculum addresses the common complaint that students are not sufficiently prepared for design challenges in their careers in industry (Buckley et al., 2008b; Hecht & Werner, 2014).

SRC solutions have been implemented successfully under different use cases (Buckley, 2009). However, despite the noticeable benefits of SRC emanating from the case studies conducted by respectable universities (e.g. University of Buffalo) and industry stakeholders, the panoptic implementation of SRC within universities across the world is deficient, mainly because there are no standardised guidelines or models to aid its implementation. Thus, the focus in this study is on a hackathon model, which could be used as an approach for stimulating and maintain students' interest in CS disciplines, especially within and ODL environment.

ODL environment: opportunities and challenges

The University of South Africa (UNISA) is the largest dedicated Open Distance Learning (ODL) organisation in South Africa. The institution is structured into six (6) colleges offering a wide range of academic and vocational programmes, including computer science and information systems (Wessels, 2012). The average number of students enrolled at UNISA was over 300 000 in 2012. The College of Science, Engineering, and Technology (CSET) accounted for only 6.3% of the overall student enrolments (University of South Africa, 2014). On a yearly basis, about 12% of the students complete their qualifications, and this is attributed to the fact that most of the students study part-time, thus would normally take longer to complete their qualifications.

The overall objective of computer science and information systems courses at UNISA is to prepare students to be socially responsible, knowledgeable and proficient in a computing-related profession. However, due to the distance teaching mode, face-to-face contact between academic staff and students is mostly limited. In addition, some students also face challenges of work-integrated learning, where they do not get the opportunity to apply what they have learned in a real-life environment, unless they are employed. Nevertheless, other initiatives to address some of these problems are being sought including community engagement, e-tutoring and extensive use of Information and Communication Technologies (ICTs) (Abdullah & Mtsweni, 2014). In this article, the focus is on the CS discipline, and the intervention that is proposed to address the low interest in CS and to change some of the misconceptions is the hackathon approach, which is discussed in the following subsection.

Hacking Culture

Although the term ‘hacking’ tends to be interpreted differently under different contexts, it still carries a negative connotation (Briscoe & Mulligan, 2014; Watters, 2012), particularly within the information security domain. A hacker is often referred to as a computer intruder who commits computer-related criminal activities, such as surreptitiously accessing computer systems for malicious reasons (Warren & Leitch, 2010). However, in this article, a different perspective and meaning is adopted. A clear distinction is made between a hacker and a cracker. For instance, an individual who breaks into computer systems to commit illegal activities is referred to as a *cracker*. On the other hand, a *hacker* is defined as an individual who is technically adept and has passion for solving problems within a community environment (Raymond, 2001).

The hacking philosophy adopted in this article has been exploited in a number of environments (Briscoe & Mulligan, 2014; RHoK, 2009; Vivacqua & Borges, 2012; Wiggins et al., 2014). It is important to note that the hacking philosophy is not only limited to computers or software, but could be applied in a number of domains, such as music, electronics, or any level of ‘science or art’ (Raymond, 2001). This culture spawns from the open source approach of developing technological solutions within a community, where everyone, irrespective of background or expertise, is encouraged to contribute towards addressing existing real-life challenges. Hence, the hacking culture is not only about programming or software coding, but involves a number of iterative steps (e.g. research, design, and analysis) to address complex and simple computing challenges. The hacking culture is closely linked to a number of computer science principles. For instance: hackers strive for realising their passion of computers by working with others to solve real problems for real people. The main motivation behind the hacking culture is about participation, contribution, and learning. In various instances, the hacking culture is practised during the hackathon events, which are discussed in the next section.

Hackathons

Hackathons can be loosely defined as marathon coding events that bring together different stakeholders to build rapidly or hack prototypes that could address technological challenges within a particular domain (Briscoe & Mulligan, 2014; NASA, 2010; Watters, 2012; Wiggins et al., 2014). The emergence of hackathons dates back to 1960 (Levy, 2010). However, their extensive use within the software development domain started to emerge in the 90s when the use of computer software became significant. Today, hackathons are a norm in large organisations such as Facebook, Yahoo, Google, and Microsoft (Briscoe & Mulligan, 2014). These events are hosted in these large organisations for many reasons, such as to build new solutions, to empower a community of developers, to entice developers to embrace latest technologies, and to recruit bright software developers into these organisations (Briscoe & Mulligan, 2014; Calco & Veeck, 2015).

The general focus of these events is on ‘rapid and iterative software development’, where a community of developers, analysts, researchers, subject-matter experts, local communities, and related stakeholders collaborate to design, code, and build testable software prototypes (Briscoe & Mulligan, 2014; Chowdhury, 2012).

3. RESEARCH AIMS AND RESEARCH METHODOLOGY

The following subsections discuss the research objectives and the research methods used to arrive at the research findings that are presented in Section 5.

Research Aim

The main aim of the research reported in this article was to investigate and understand the hackathon approach and determine if it was suitable in stimulating and maintaining students’ interest in computing.

Secondary objectives included an investigation to determine if approaches such as the hackathon programmes could change the 'false' students' perceptions about CS. The potential impact of hackathons in supporting students via mentoring, networking, and collaboration with external stakeholders was also investigated.

Research Methodology

An exploratory case study approach (Yin, 2009), supported by document analyses, participant observations (Guest, Namey & Mitchell, 2013), and open-ended interviews, was used for this research study. The case study method was chosen and preferred as it provides opportunities to collect data using multiple sources of data (Tellis, 1997; Yin, 2009). In addition, the case study method was chosen because of its 'ability to examine in-depth' a phenomenon within a real-life setting (Yin, 2009). A single case study was then designed within an existing community engagement project, called Computing Pro Bono (cf. Section 4). The case study was conducted and administered over a period of 36 months, spanning six (6) formal hackathon events. The major component of the case study focused on participant observations, open-ended interviews, and expert evaluations of the prototypical solutions, which are not discussed in this article due to space limitations.

The participants who formed part of the case study were mainly software developers, subject-matter experts, computing students, learners, community representatives, problem owners, and business owners. Data collection was accomplished through different phases. In Phase 1, a thorough searching through the Web for hackathons-related online news reports, personal blogs, and hackathon events pages was done. This was done so as to understand fully the purpose of the hackathons from different perspectives. It was also important to understand why these hackathon events have rapidly found their way even in larger organisations (Briscoe & Mulligan, 2014; Wiggins et al., 2014), such as Google. Phase 1 was also crucial for understanding the impact that these types of programmes have on those who participate in them, particularly computing students.

In Phase 2, data was continuously collected and analysed during the six (6) different hackathons that formed part of the case study. During Phase 2, data was collected through open-ended interviews with randomly selected participants and field notes were recorded during participant observations. A total of 30 interviews were conducted during the period of the study, with about five (5) interviews conducted at each of the events. The interviewees were mainly with software developers, subject-matter experts, students, and community members. Participant observation was chosen because it enabled the researchers not to be bystanders, but to be directly involved in all the activities that formed part of the case study (Guest et al., 2013: 79).

The case study evidence was analysed using thematic analysis and activity theory (De Souza & Redmiles, 2003; Joffe, 2011; Vakkayil, 2010). Thematic analysis 'focuses on identifiable themes and patterns' of activities from research data (Joffe, 2011), whilst activity theory provides elements that make it possible to understand and analyse the relevance of collaborative work (Hashim & Jones, 2007). In addition, activity theory provides aspects that are useful for understanding human activities within a specific environment (e.g. community engagement project). In Phase 3, the proposed model was evaluated by involving expert reviews made up of five (5) experts, mainly from academia, private and public sector. The expert reviews were only conducted during the last hackathon that formed part of this study. The experts evaluated the model based on the following aspects:

- **Impact:** the impact that the model could have in stimulating students' interest in CS
- **Complexity:** the complexity of the model when considering different aspects, such as involvement of multi-disciplinary stakeholders

- **Relevance:** the relevance of the model within the ODL environment and in addressing challenges of low enrolment in CS.
- **Sustainability:** the sustainability of the model in achieving the desired results now and in the future.

A simple 1 (Poor) – 5 (Excellent) scale was used to quantitatively evaluate the model and experts' comments and suggestions were used to qualitatively evaluate the model.

4. CASE STUDY – COMPUTING PRO BONO

The case study that informed this research was undertaken within a project called Computing Pro Bono. The project has been running since 2012. The project is a community engagement and outreach initiative in the School of Computing at UNISA. It is purported to exploit the computing and research expertise of the computing academics, students, and external stakeholders to develop or hack open Information and Communication Technologies (ICTs) solutions that could address social and humanitarian challenges. Community engagement typically finds expression in a variety of forms, ranging from informal and relatively unstructured activities to formal and structured academic programmes addressed at particular community needs. Some of the activities might be conducive towards the creation of a better environment for community engagement and others might be directly related to teaching and research (UNISA, 2008). Community engagement is also one of three core responsibilities of higher education, together with research and teaching, even though it seems to have been neglected (Council of Higher Education, 2010).

The main objective of this specific project is to foster collaborations between students, staff, and external stakeholders in addressing some of the social challenges using computing. The other aim is to provide a work-integrated learning environment for computing students, who are often neglected when it comes to industry exposure.

Approximately, a total of 400 participants, including computing students, learners, subject-matter experts, researchers, business analysts, developers, and representatives of local communities gathered and collaborated to tackle different social challenges in various domains over the six (6) hackathon events that formed part of the case study from 2012 until the end of 2014. Each hackathon was hosted over a two-day period (from Saturday until Sunday) spanning over 40 hours. Participants had an option to attend the events physically or virtually participate using tools, such as Google Plus or Skype.

The participation was voluntary and opened to everyone who had the interest to contribute in the identified projects. Challenges or projects that were tackled by the volunteers mainly originated from communities, schools, non-profit organisations, experts, and in some instances, from computing students. At the end of each session, all the projects were evaluated against set criteria by a team of subject-matter experts. The evaluation of these projects is beyond the scope of the research results presented in this article.

5. CASE STUDY FINDINGS

In this section, we present and discuss the research findings that emerged from the case study using thematic analysis and activity theory as explained in Section 3. In terms of thematic analysis, a number of common themes were derived from the research data and these are discussed in conjunction with the same data that was analysed using activity theory. It is worth noting that data collection, analysis, and reporting in this study was guided by the research ethics code of the university (University of South Africa, 2015), and for purposes of ensuring confidentiality and anonymity of respondents, including experts, no direct names of the respondents are exposed in this report. Respondents' answers during the interviewed are referenced using R1, R2,...Rn and experts are referenced using E1, E2, and so forth.

Briefly, activity theory focuses on six elements when analysing human activity, and these are (1) objects, (2) subjects, (3) community, (4) division of labour (5) rules, and (6) tools (Constantine, 2009; Vakkayil, 2010). The results are discussed according to the derived themes and based on the elements defined by the activity theory.

Challenges

In all hackathons under the aforementioned case study, the main activity was about delivering computing solutions within a short period of time focusing on addressing identified social challenges. Based on the activity theory, *objects* are equivalent to challenges. These are the intended activities that role players engage with to achieve a particular outcome (Hashim & Jones, 2007). Some of the challenges or projects that were tackled during the hackathons included projects, such as social informant, water detective, water pump monitor, micro worker, donate-my-school-stuff, smart-citizens, and many others. Details on some of these projects can be found in these reports (CSET, 2012, 2013; RHoK, 2012). These projects were initiated by different stakeholders, such as non-governmental organisations, private and public schools, and subject-matter experts. The challenges presented integrated a number of computer science concepts, such as searching algorithms, graph theories, and others.

During all the hackathons, it was also observed that although the main activity was about software development, other sub-activities were also performed by non-technical or novice participants, such as researching the presented challenge, gathering requirements from subject-matter experts, managing the to-do tasks list, and designing of user interfaces. Most of the challenges presented offered students opportunities to apply what has been learned in class in practice, do further research on computer science and information systems concepts, reflect on various concepts in practice, and in some way confront social good issues in a collaborative environment.

Participants

The challenges presented in the hackathons were normally addressed in teams of about two to eight members. The participants, which are referred to as *subjects* in the activity theory (Vakkayil, 2010), came from different fields and had different skills sets; which were not only limited to technical programming. From the data collected, it became apparent that the subjects were instrumental in making the hackathons successful, particularly the subject-matter experts, developers, and organisers. It was observed that students engaged heavily with experts in the beginning, mainly for purposes of understanding the social challenges and possible approaches to addressing the challenge. These students brought a lot of dynamics into different challenges as they were open-minded and attended these events to 'learn, and also practically apply what [we] have learnt in the classroom' said one student (R23). Most of the students interviewed find the whole concept of hackathons very useful, giving them a chance to learn and 'network with expert developers' (R10), but also an opportunity to be part of project teams that are capable of delivering solutions within a short space of time, using a number of open source technologies.

Collaborations

In all the hackathons that formed part of the case study, the aspect of *community* and collaborative work was central. In a number of instances, communities were formed before the events, either for problem finding and formulation or for identifying stakeholders that might benefit from the proposed solution(s). The challenges (i.e. projects), although many required technical solutions; were tackled by appreciating all the contributions of individuals who participated. In this instance, students found the opportunity of addressing some of these challenges with others rewarding. One expert asserted:

students not only get the opportunity to understand the value of computer science in terms of social good, but they also get the opportunity to engage with industry professionals and subject-matter experts, who have already passed the road that they are currently travelling (E5).

It should also be emphasised that by being part of collaborative teams, students are also exposed to 'mentoring and work-integrated learning opportunities; which are sometimes limited within an ODL environment' (E2).

It was also observed throughout the different events that hackathons do encourage the notion of 'working together to achieve more' (R18) and it is believed that students' participation in such projects is vital for their social and practical understanding of computer science concepts, and for maintaining their interest in CS.

Structure, Rules, and Technologies

From the case study, it became apparent that activities within the projects are somehow semi-structured, with participants, especially students deciding where they would want to be involved. In many instances, most of the participants were involved in the hackathon for social coding, thus most of the attendees are software developers. In addition, there are normally some unwritten rules that govern how teams engage in activities. Typically, subject-matter experts would drive the requirements of the social solution meant to address the identified challenge. Conversely, seasoned developers would lead the manner in which the development of the solution will be approached, such as what software development methodologies are used and which technologies are useful and relevant for the identified challenges.

Computing students would normally be tasked with setting up the environment, such as the relational database, designing simple user interfaces, and performing project management duties. However, depending on the technical skills of the student, more challenging tasks could also be allocated. However, it should be noted that for all the hackathons within the case study, the main objective of involving computing students, mostly from the ODL environment, was to investigate and understand the value of hackathons in stimulating and maintaining their interest in the CS field.

Activity theory postulates that *subjects* engage with the *object(s)* by using different types of tools (Jonassen & Rohrer-Murphy, 1999). Open and mobile technologies were dominant, mainly due to the fact that they are easily accessible, easy to use, and normally receive wide support from the open source communities. It is also worth noting that mobile devices are quite efficient as experimental tools for rapidly testing various computer science concepts. This is because they have similar capabilities as traditional computers, such as network access, processing and storage.

Nevertheless, it became apparent during the interviews with some students that a technology choice was based on previous experience, awareness of the tool, and availability of online resources about the technology (e.g. documentation and tutorials). In some instances, it was also based on what the team deemed as appropriate. In some cases, teams chose a technology on which they had little working experience. This as explained by one software developer interviewed, was for purposes of 'trying and learning something new' (R11).

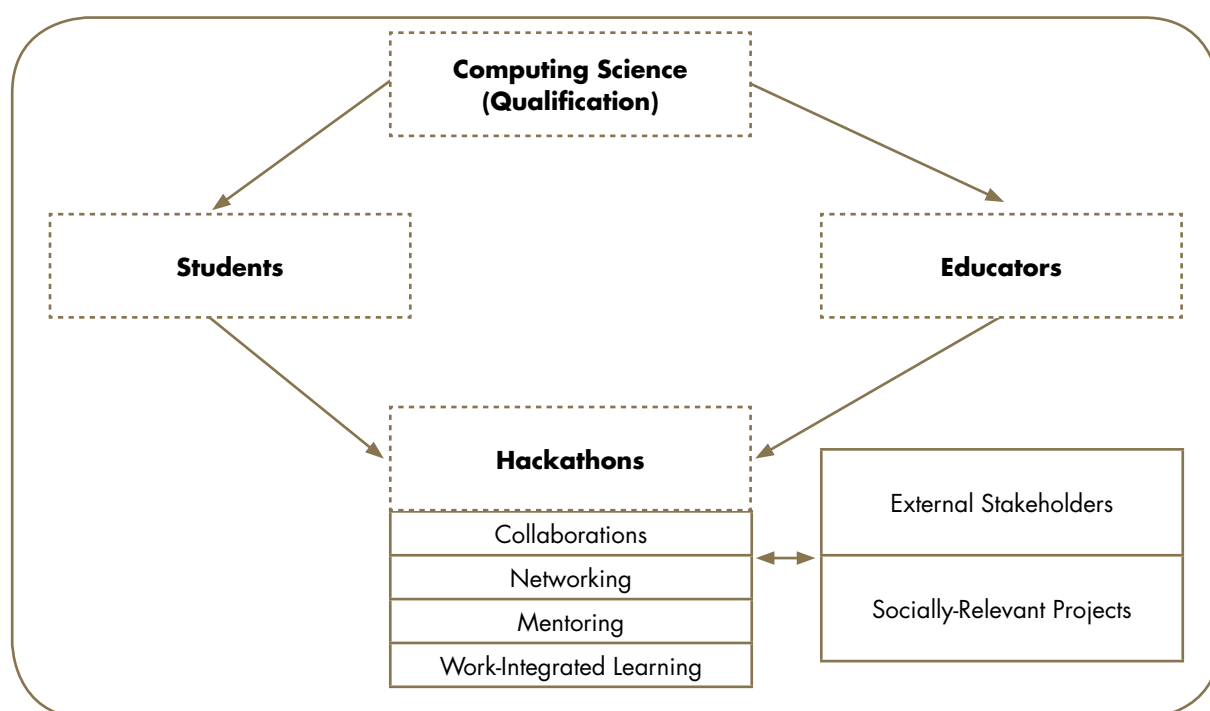
From the research findings, it is apparent that hackathons have the potential to stimulate and maintain students' interest in computer science. At the same time, the hackathon approach provides a suitable environment where students could easily understand the social relevance of CS. The research findings also suggest that if students are able to see the value of what they are learning in class within a real-life setting, their passion and participation in the field increases. This was observed throughout the different hackathon events that formed part of the case study. Lastly, it was also observed that during the first attendance of a hackathon, many students had wrong perceptions of what the whole programme is all about. Some students interviewed during the first two (2) hackathons thought that it was about 'breaking into bank systems' (R3, R8), and after the first event, particularly when their projects are evaluated by the experts, their thinking completely transformed.

The following section presents a hackathon model that emanated from the case study and could be used as a foundation to stimulating and maintaining students' interest in CS within an ODL environment. The evaluation of the model is also discussed.

6. HACKATHON MODEL

From the results of the case study conducted as described in Section 5, the hackathon model as depicted in Figure 1 was formulated. The purpose of the model is to capture key elements that are essential toward stimulating and maintaining students' interest in CS. The model is composed of various integrated elements, with the root element being the CS qualification.

Figure 1:
Suggested hackathon model



As it may be noted in Figure 1, the facilitation of the CS qualification is managed by educators with students being the key participants. On average, the five (5) experts (E1 – E5) rated the complexity of the model at 3.6, which is classified between Good and Great. It was noted that the involvement of different stakeholders should be synergistic, where students and educators continuously engage through various pedagogical strategies for purposes of promoting better learning and understanding. Within this element, it is also important to start reflecting on the social importance and impact of CS, possibly through small and social class-based projects.

A direct connection between theory and practice need to be formulated, using programmes (e.g. *hackathons*) that encourage students and educators working together with external stakeholders (e.g. communities and subject-matter experts) in socially relevant projects. The projects need to be scoped such that some of the computing principles taught in class could be implemented in practice, thus 'enabling current and prospective students to better understand the relevance of CS in the real-world settings'(E3). The process of aligning the CS curriculum with hackathons is a process that needs to be given enough attention, and improved over time through experience and participation by both students and academics. All the experts evaluated the proposed model to be of the higher impact (score of 4), and having a great

potential to address some of the challenges faced by computing students (e.g. work-integrated learning). The potential impact is elaborated as follows: The hackathon approach could also be incorporated in the CS qualification to provide students progressively with opportunities *for collaborations* with the community and industry experts, thus enriching their perceptions about CS. *Networking* opportunities with other individuals in the same field (e.g. software developers) could also clarify a number of concerns for CS students, particularly when networking with those who are already applying what was taught in class in a real world. The environment (i.e. hackathon approach) could also enable experienced professionals who are already in industry to 'mentor and engage' (E1) students on various aspects related to computing. Another important aspect that could be tackled with the hackathon approach is the 'work-integrated learning' (E1, E4), which is possible to implement and complete over multiple hackathon sessions and where deliverables could be social projects that are ready to be deployed with the selected community.

The ultimate goal of the hackathon model should be to ensure that students' interest in CS is stimulated and maintained, and that students' perceptions about CS as being complex and asocial are transformed. On average, the experts evaluated the sustainability of the proposed model at 4.5. They mostly cited its implication on addressing social challenges in the communities using technology and alignment with the education sector, where practical work is essential for students to be prepared for the real world.

Lastly, the implementation of the model could differ from one setting to the next. For instance: in an ODL environment where students are mainly distributed across different locations, virtual hackathons or even different hackathon chapters in different locations or regions could be considered. In order to also ensure seamless integration of such an approach into the CS qualification, it might be useful to assess students on the deliverables that emanate from different events. With regards to the relevance aspect, experts agreed that such a model is relevant, and not only to the ODL environment, but to other traditional universities, businesses, and the public sector. However, care should be taken that projects that are started are completed, and students take time to understand the environment where the developed solutions are meant to be deployed. Experts also warned that it might be difficult for the model to stimulate directly students' (especially those not in the system already) interest in CS, but mostly agree that it is relevant for maintaining students' interest in computing qualifications.

7. CONCLUSION

In this study, we have demonstrated the possibilities of using the hackathon approach as a means to stimulate and maintain students' interest in computer science. Through an exploratory case study, we have highlighted that community engagement projects, such as Computing Pro Bono, when implemented within the context of hackathons, can enable computing students to collaborate with communities, subject-matter experts, and most importantly industry professionals in order to better understand the relevance of CS in a real-world setting. The potential of hackathons in delivering socially-relevant solutions within a short space of time is self-evident from the case study conducted, and this provides a good platform for students to apply what they have learned. From the research findings, it was discovered that most students who participated in the hackathons that formed part of the case study found the hackathon environment to be useful for their learning and above all for changing their perceptions about computing.

The main contribution from this article is, therefore, a proposition of a hackathon model as one possible approach for increasing students' interest in computer science and encouraging their involvement in using their computing skills and knowledge in solving social pressing issues affecting their local communities. Further research work points to the replication of the study with more computing students and the evaluation of the model in other environments, such as a traditional university. The efficacy of the proposed model in addressing the low interest in computer science also requires further investigation as noted during the expert reviews.

REFERENCES

- Abdullah, H. & Mtsweni, J.S. (2013) 'A model for Work Integrated Learning (WIL) in an Open Distance Learning (ODL) environment' *Proceedings of the 18th WACE World Conference on Cooperative & Work-Integrated Education*. Durban, South Africa. pp.1-13.
- Abdullah, H. & Mtsweni, J. (2014) 'The role of e-tutors in promoting e-learning using Web 2.0 technologies' In J. Van Niekerk (Ed.) *Proceedings of the African Cyber Citizenship Conference* pp.67-72. Nelson Mandela Metropolitan University, South Africa.
- Anderson, N., Lankshear, C., Timms, C. & Courtney, L. (2008) "'Because it's boring, irrelevant and I don't like computers": Why high school girls avoid professionally-oriented ICT subjects' *Computers & Education* 50(4) pp.1304-1318. doi:10.1016/j.compedu.2006.12.003
- Briscoe, G. & Mulligan, C. (2014) Digital Innovation: The Hackathon Phenomenon (6). <http://www.creativeworkslondon.org.uk/wp-content/uploads/2013/11/Digital-Innovation-The-HackathonPhenomenon1.pdf> (Accessed 13 November 2014).
- Buckley, M. (2009) 'Viewpoint: Computing as social science' *Communications of the ACM* 52 (4) pp.29-30. doi:10.1145/1498765.1498779
- Buckley, M., Nordlinger, J. & Subramanian, D. (2008a) 'Socially relevant computing' *Proceedings of the 39th SIGCSE Technical Symposium on Computer Science Education*. Portland, OR, USA: ACM. doi:10.1145/1352135.1352255
- Buckley, M., Nordlinger, J. & Subramanian, D. (2008b) 'Socially relevant computing' *SIGCSE Bulletin* 40(1) pp.347-351. doi:10.1145/1352322.1352255
- Calco, M. & Veeck, A. (2015) 'The Markathon: Adapting the Hackathon Model for an Introductory Marketing Class Project' *Marketing Education Review* 25(1) pp.33-38. <http://www.tandfonline.com/doi/abs/10.1080/10528008.2015.999600>
- Chowdhury, J. (2012) 'Hacking Health: Bottom-up Innovation for Healthcare' *Technology Innovation Management Review* (July 2012) pp.31-35.
- Constantine, L.L. (2009) 'Human Activity Modeling: Toward A Pragmatic Integration of Activity Theory and Usage-Centered Design Human-Centered Software Engineering' In A. Seffah, J. Vanderdonck & M.C. Desmarais (Eds.) Springer: London. pp.27-51. doi:10.1007/978-1-84800-907-3_3
- Council of Higher Education. (2010) 'Community Engagement in South African Higher Education' http://www.che.ac.za/documents/d000204/Kagisano_No_6_January2010.pdf. (Accessed 12 December 2012).
- CSET. (2012) 'Computing Pro Bono' <http://www.unisa.ac.za/cset/news/index.php/2012/06/computing-pro-bono/> (Accessed 18 May 2013).
- CSET. (2013) 'Computing Pro Bono Hacks for Humanity' <http://www.unisa.ac.za/cset/news/index.php/2013/06/computing-pro-bono-hacks-for-humanity/> (Accessed 22 July 2014).
- De Souza, C.R.B. & Redmiles, D.F. (2003) 'Opportunities for Extending Activity Theory for Studying Collaborative Software Development' *8th European Conference in Computer-Supported Co-operative Work and Social Computing (CSCW) (Workshop in Applying Activity Theory to CSCW Research and Practice)*. Helsinki, Finland.

Firth, R. (2014) 'South Africa needs to get kids interested in computer science, or risk falling badly behind | memeburn' <http://memeburn.com/2014/09/south-africa-needs-get-kids-interested-in-computer-science-or-risk-falling-badly-behind/> (Accessed 11 February 2015).

Galpin, V.C. & Sanders, I.D. (2007) 'Perceptions of Computer Science at a South African university' *Computers & Education* 49(4) pp.1330-1356. doi:10.1016/j.compedu.2006.02.008

Guest, G., Namey, E. & Mitchell, M.L. (2013) *Collecting Qualitative Data: A Field Manual for Applied Research*. London: SAGE Publication, Inc.

Hashim, N. & Jones, M.L. (2007) 'Activity Theory: A framework for qualitative analysis' *4th International Qualitative Research Convention (QRC)*. PJ Hilton, Malaysia.

Hecht, B. & Werner, J. (2014) 'The KumbhThon technical hackathon for Nashik: A model for STEM education and social entrepreneurship' *IEEE Intergrated STEM Education Conference (ISEC)*. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6891024

Hill, C., Corbett, C. & St. Rose, A. (2009) 'Why So Few? Women in Science, Technology, Engineering, and Mathematics' *American Association of University Women*. <http://eric.ed.gov/?id=ED509653>

Joffe, H. (2011) *Thematic analysis*. Chichester, UK: John Wiley & Sons.

Jonassen, D. & Rohrer-Murphy, L. (1999) 'Activity theory as a framework for designing constructivist learning environments' *Educational Technology Research and Development* 47(1) pp.61-79. doi:10.1007/bf02299477

Levy, S. (2010) *Hackers: Heroes of the Computer Revolution - 25th Anniversary Edition*. California: O'Reilly Media, Incorporated. <http://books.google.ca/books?id=mShXzzKtpmEC>

Mtsweni, J. & Abdullah, H. (2013) 'Stimulating Socially Relevant Computing through Community Engagement: an ODeL perspective' *iNEER ICEE ICIT Conference*. Cape Town, South Africa.

NASA. (2010) Random Hacks of Kindness (RHoK). http://www.nasa.gov/open/rhok_2010_prt.htm (Accessed 12 May 2013).

Papastergiou, M. (2008) 'Are Computer Science and Information Technology still masculine fields? High school students' perceptions and career choices' *Computers & Education* 51(2) pp.594-608. doi:10.1016/j.compedu.2007.06.009

Pauca, V.P. & Guy, R.T. (2012) 'Mobile apps for the greater good' *Proceedings of the 43rd ACM technical symposium on Computer Science Education - SIGCSE 12* p.535. New York: ACM Press. doi:10.1145/2157136.2157291

Raymond, E.S. (2001). How to become a Hacker. <http://www.catb.org/esr/faqs/hacker-howto.html> (Accessed 18 May 2013).

RHoK. (2009) What is Random Hacks of Kindness? <https://sites.google.com/a/rhok.org/www/home> (Accessed 12 May 2013).

RHoK. (2012) RHoK Pretoria - H2O Detective are the winners! www.rhok.org/blog/rhok-pretoria-h2o-detective-are-winners

- Richard, G. & Kafai, Y. (2015) 'StitchFest: Diversifying a College Hackathon to Broaden Participation and Perceptions in Computing' *SIGSE '15 Proceedings of the 46th Technical Symposium in Computer Science Education* pp.114-119. <http://dl.acm.org/citation.cfm?id=2677310>
- Tellis, W. (1997) 'Application of a Case Study Methodology' *The Qualitative Report* 3 (3) <http://www.nova.edu/ssss/QR/QR3-3/tellis2.html>
- UNISA. (2008) Community Engagement and Outreach Policy. http://cm.unisa.ac.za/contents/departments/community/docs/CommEngagemPolicy_toManCom_26an08.pdf (Accessed 18 May 2013).
- University of South Africa. (2014) Unisa Online - Facts & figures. <http://www.unisa.ac.za/Default.asp?Cmd=ViewContent&ContentID=18123> (Accessed 10 January 2015).
- University of South Africa. (2015) Research ethics. <http://www.unisa.ac.za/Default.asp?Cmd=ViewContent&ContentID=27669> (Accessed 24 July 2015).
- Vakkayil, J.D. (2010) 'Activity Theory: A Useful Framework for Analysing Project-Based Organizations' *Vikalpa: The Journal for Decision Makers* 35(3) pp.1-18. doi: <http://www.vikalpa.com/pdf/articles/2010/page-vol-35-1-18.pdf>
- Vivacqua, A.S. & Borges, M.R.S. (2012) 'Taking advantage of collective knowledge in emergency response systems' *Journal of Network and Computer Applications* 35(1) pp.189-198. doi:10.1016/j.jnca.2011.03.002
- Warren, M. & Leitch, S. (2010) 'Hacker Taggers: A new type of hackers' *Information Systems Frontiers* 12(4) pp.425-431. doi:10.1007/s10796-009-9203-y
- Watters, A. (2012) Designing Education Hackathons. <http://hackededucation.com/2012/08/06/education-hackathon/> (Accessed 19 May 2013).
- Wessels, R. (2012) 'The reception of satellite broadcasting in public administration teaching at the University of South Africa' *Mediterranean Journal of Social Sciences* 3(12) pp.150.
- Wiggins, A., Gurzick, D., Goggins, S. & Butler, B. (2014) 'Quality Hackathon' *Proceedings of the 18th International Conference on Supporting Group Work - GROUP '14* pp.321-323. New York, USA: ACM Press. doi:10.1145/2660398.2660429
- World Economic Forum. (2012) The Financial Development Report. http://www3.weforum.org/docs/WEF_FinancialDevelopmentReport_2012.pdf (Accessed 12 February 2015).
- Yin, R.K. (2009) *Case Study Research - design and methods* (4th ed.) California: SAGE Publications.

Analysis of errors due to deficient mastery of prerequisite skills, facts and concepts: A case of financial mathematics¹

Xolani Khalo, University of Fort Hare, South Africa

Anass Bayaga, University of Zululand, South Africa

ABSTRACT

The main aim of the study was (1) to identify errors committed by learners in financial mathematics, and, (2) to understand why learners continue to make such errors so that mechanisms to avoid them could be devised. It has been hypothesised that errors committed by learners in financial mathematics are not due to lack of prerequisite skills, facts and concepts. Using Newman's Error Analysis as a theoretical framework, a four-point Likert scale and a content-based structured-interview questionnaire was developed to identify the errors committed. The study was conducted by means of a case study guided by the positivists' paradigm where the research sample comprised of 105 Grade 10 Mathematics Literacy learners as respondents. A structured-interview questionnaire was used for collecting data, aimed at addressing the main objective of the study. In order to test the reliability and consistency of the items in the questionnaire, Cronbach's Alpha was calculated for standardised items ($\alpha = 0.705$). Data analysis through content analysis and correlation analysis revealed that learners tend to forget to read the instructions (A) and rounding off incorrectly (C), was weakly significant, as $p < .01$ ($r = +.31$). The hypothesis was tested through Analysis of Variance (ANOVA) revealed that errors committed by learners in financial mathematics are not due to the lack of prerequisite skills, facts and concepts, as the variables showed non-significance.

Keywords: Errors, financial mathematics, prerequisite skills, concepts

INTRODUCTION

A Mathematical Literacy (ML) teacher always administers different assessment tasks throughout the course of the year as per requirements of the National Curriculum Statements (NCS). These tasks are administered in order to determine learners' understanding of the concepts taught inside and outside the classroom. According to the Department of Education (2005: 101)

... assessment is a continuous planned process of identifying, gathering and interpreting information about the performance of learners, using various forms of assessment. It involves four steps: generating and collecting evidence of achievement; evaluating this evidence; recording the findings and using this information to understand and thereby assist the learners' development in order to improve the process of learning and teaching.

¹ Date of submission 2 May 2014
Date of acceptance 20 November 2014

Surprisingly, learners who seem to follow the trend of the lessons, commit errors when working out the tasks assigned. This stimulated the researcher to critique, understand and undertake research to try and find answers as to what are the underlying factors contributing to common errors committed by Grade 10 ML learners in financial mathematics. Financial mathematics accounts for 35% weighting of the topics in the examination, which indicates that it is more valuable in the ML curriculum (Department of Basic Education [DBE], 2011). It encompasses a number of basic mathematical skills such as: interpreting, communicating answers and calculating, number and calculations with numbers. This is where learners lose marks in their assessment tasks. Financial mathematics could be seen as the Application Topic, which according to the DBE (2011: 13) 'contain[s] the contexts related to scenarios involving daily life, workplace and business environment, and wider social, national and global issues that learners are expected to make sense of content and context'. Topics in financial mathematics include: financial documents, tariff systems, income, expenditure, profit/loss, income-and-expenditure statements, budget, interest, banking, loans and investments.

This study adds, in particular, to the small body of research in error analysis in ML. It focuses on the underlying factors related to the errors due to deficient mastery of prerequisite skills, facts and concepts. Teaching strategies that involve more of drill and practice have been replaced by the reformed approaches that recognise that errors form a valuable source of understanding learners' thinking. Teachers find it difficult to escape from learners' errors so it is worthwhile finding out why learners make them.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

Error analysis in mathematical education

By pinpointing learner errors in mathematical literacy, the teacher can provide instruction targeted to the learners' area of need. Learners who have difficulty learning mathematical literacy typically lack important conceptual knowledge for a number of reasons, including an inability to process information at the rate of the instructional pace; lack of adequate opportunities to respond; and the lack of specific feedback from the teacher regarding the misunderstanding cited.

Hodes adapted the following table from Nolting (1998: 1), which illustrates five types of errors for word problems.

*Table 1:
Types of errors for word problems*

1. Read errors	The learner cannot read a key word or symbol correctly.
2. Comprehension errors	The learner reads all the words in the problem accurately but does not understand the overall problem or specific terms within the problem.
3. Transformation errors	The learner understands what the problem requires but is unable to identify the operation or the sequence of operations needed to solve the problem.
4. Procedural errors	These include: <ul style="list-style-type: none"> • Placement errors which is incorrect sequencing of digits or alignment of algorithms. • Incorrect steps which is use of steps that are not associated with any operations. • Missing steps where steps necessary to complete a procedure are missing.
5. Encoding errors	A learner solves the problem but does not write the solution in an appropriate form.

(Adapted from Nolting, 1988: 1)

The aforementioned types of errors have been used in the identification of learner errors in the content analysis. Brodie (2005: 179) brought into the debate of learner errors 'Situative perspectives: Situative perspectives argue that what a learner says and does in the classroom make sense from the perspective of his/her current ways of knowing and being, his/her developing identity in relation to mathematics and to his/her previous experiences of learning mathematics, both in and out of school. After engaging with learners in class discussions of a particular topic, Brodie developed a coding scheme to categorise learners' contribution (Brodie cited in Khan & Chishti, 2011: 656).

Table 2:
Brodie's coding scheme to categorise learners' contribution

Basic Error	An error not expected at the particular grade level, indicates that the learner is not struggling with the concepts that the task is intended to develop, but rather with the other concepts that are necessary for completing the task and have been taught in previous years
Appropriate Error	An incorrect contribution expected at the particular grade level in relation to the task
Missing Information	Correct but incomplete and occurs when the learner presents some of the information required by the task but not all of it
Partial insight	Learner is grappling with an important idea, which is not quite complete, nor correct, but shows insight into the task
Complete correct	Provides an adequate answer to the task or question
Beyond task	Related to the task or topic of the lesson but goes beyond the immediate task and/or make some interesting connections between ideas

(Brodie, 2005: 177)

Riccomini (2005: 233) brought into perspective (1) *unsystematic errors*: unintended, non-recurring wrong answers which learners can readily correct by themselves; (2) *systematic errors*: though they are recurring wrong response methodologically constructed and produced across space and time, they are symptomatic of a faulty line of thinking that causes them to be referred to as misconceptions. Elbrink (2008: 2) categorises learners' mathematical errors into three main categories: calculation errors, procedural errors and symbolic errors.

Table 3:
Summary of the above-stated categories of learner mathematical errors

Error Category	Description
1. calculation errors	<ul style="list-style-type: none"> mistakes in addition, subtraction, multiplication and division
2. procedural errors	<ul style="list-style-type: none"> occurs when learner computes or applies an incorrect procedure and symbolic errors
3. symbolic errors	<ul style="list-style-type: none"> occurs when learners falsely relate mathematical problems that use similar symbols

Elbrink (2008) elaborated each of the categories as: (1) an error of numbers, which she attributes to carelessness and lack of attention. She further suggested the possible solution to the calculating error is incorporation of an error checklist into a regular classroom routine and procedures. This will allow learners to assess themselves and identify repeated errors and mistakes in their work. (2) Learners are

usually taught in drill and practice and so be automated to carry out specific mathematical tasks rapidly and effectively and can be confused for conceptual understanding. Therefore they cannot recognise the importance of applying a procedure correctly.

Procedural errors suggest that learners do not understand the concepts related to the procedure and are unable to build procedure from conceptual knowledge. She suggested the introduction of the concepts before the procedure, concrete manipulation and real-life application. In her elaborate discussion of procedural errors she brings up the importance of threshold concept which forms part of the theoretical framework of this study. Finally (3), learners try to create meaning in the patterns of mathematical symbols and signs that they see in front of them rather than trying to understand. The identification of errors in the content analysis is based on the aforementioned errors. The errors described in Tables 1, Table 2 and Table 3 have been utilised to categorise the identified errors in this study. The procedural errors which were identified during content analysis could be eradicated from learners by means of teaching that is embedded on the threshold. It is strongly associated with the errors due to incorrect association or rigidity of thinking which was stated as the second research question. The researcher chose to name this particular type of error as 'Radatz' as that also describes it.

In the aforementioned discussions, a number of studies by different researchers have been reviewed; this study focused on the Radatz (1979) classification of errors which brings about the underlying factors that can be associated with learner errors. The types of errors discussed below form a fundamental part of the research propositions of this study.

One should, of course, acknowledge that errors are also a function of other variables in the education process which classifies errors according to information processing. Research questions and hypotheses of the study have been formulated based on the Radatz (1979: 164) classification of errors according to individual difficulties of learners.

Mathematical thinking

Studies have shown that mathematical thinking can be described in terms of two distinct but interrelated components: (1) a non-verbal spatial understanding of quantity, and, (2) a verbal understanding that is related to language and symbolic reasoning (Radatz, 1979; Murray, 2012). According to Setati as cited in Tshabalala (2012: 22) 'in order to develop mathematical thinking, learners have to be able to communicate mathematically'. Teachers should encourage learners to use correct mathematical language and avoid oversimplification through the use of everyday English language. The aforementioned description of mathematical thinking can be closely correlated to the learning process of mathematical literacy.

Goswami (2008: 282) states that 'small amounts of training can lead to rapid improvement in the strategic use of rehearsal, with accompanying improvement in recall'. The recall of the basic formula and the relevant algorithms is an important skill as when learning financial skills the use of formula may be required.

Understanding in the learning process of mathematics

Understanding in the learning process of mathematics can be categorised in two, namely: (1) Instrumental understanding is demonstrated by someone who uses rules without understanding (rules such as to divide by a fraction you turn it upside down and multiply), (2) Relational understanding occurs when one has built up a conceptual structure of mathematics.

'Working memory is especially critical to mathematics learning because mathematics learning places frequent demands on working memory' (Cathercole et al., cited in Soendergaard & Cachaper, 2008:15).

Working memory is therefore the system that actively holds multiple pieces of transitory information in the mind, where they can be manipulated. Students must remember intermediate products of calculations in order to solve problems. Interconnected problems are more common in financial mathematics especially in the income, expenditure and taxation sections. An ability to recall the acquired concepts and skills can be regarded as a good working memory; it has been shown to correlate with successful mathematics learning.

'Relational understanding/thinking occurs when one has built a conceptual structure (schema) of mathematics and therefore both know what to do and why when one solves a mathematical problem' (Soendergaard & Cachaper, 2008: 16). For instance, when dealing with simple and compound interest, the interest may be compounded monthly for three years; that then demands rational thinking of the fact that three years is thirty six months in trying to find the value of n . Rational thinking needs to be developed through teaching and learning in the classroom and thus will play a major role in eliminating or reducing the errors committed by learners.

Theoretical Framework

This study was guided by three theoretical frameworks: Polya's problem-solving techniques, threshold concepts/ troublesome knowledge of Meyer & Land (2006), and Newman's error analysis in deconstructing the concept of error analysis.

Polya's problem-solving techniques

Polya developed four basic principles that need to be considered during problem solving. Based on the principles the four steps that need to be followed during problem solving were developed later. These might be useful to the learners' problem-solving techniques and the Mathematical thinking concept by educators can also assist in eliminating the errors. These techniques according to Polya (1945) are: 1) Understanding the problem; 2) Devising a plan; 3) Carrying out the plan; and 4) Looking back.

Threshold concepts and troublesome knowledge

'A core concept is a conceptual "building block" that progresses understanding of the subject; it has to be understood but does not necessarily lead to a qualitative view of the subject matter' (Meyer & Land 2006: 4). As in the aforementioned discussion of Polya's problem-solving techniques, success in problem solving does not solely depend on the acquisition of concepts but also depends on the choice of the relevant problem-solving technique.

Deficient mastery of prerequisite skills, facts and concepts has been hypothesised in the current study as one of the underlying factors that contribute to learners committing errors in financial mathematics. According to Ratadz (1979) deficit in basic prerequisites includes ignorance of algorithms, inadequate mastery of basic facts, incorrect procedures in applying basic mathematical techniques, and insufficient knowledge of necessary concepts and symbols.

Newman's Error Analysis

The current study was guided by Newman's Error Analysis technique in the error analysis of learners' work. Newman's Error Analysis (NEA) provided a framework for considering the reasons that underlay the difficulties students experienced with mathematical word problems and a process that assisted teachers to determine where misunderstandings occurred. NEA also provided directions for where teachers could target effective teaching strategies to overcome learners' errors (White, 2010: 129-148). By pinpointing the errors committed by learners in financial mathematics, teaching can be directed towards the correct procedure of solving the identified problem. The Newman's error analysis and follow-up strategies have

helped learners with their problem-solving skills, and teachers developed a much more consistent approach to the teaching of problem solving (White, 2010).

Specific Objective

To be able to reduce and/or eliminate errors committed by learners, both learners and educators need to be able to (1) identify the errors and (2) understand why learners continue to commit the errors and then be able to avoid the identified errors. The research focused on the mechanisms involved in errors as applied in financial mathematics.

Research Questions

1. What are the types of errors learners encounter in financial mathematics?
2. Why do learners continue to commit errors of similar nature from previous given task(s)?

Research Hypothesis

H₀: Errors committed by learners in financial mathematics are due to deficient mastery of prerequisite skills, facts and concepts.

H₁: Errors committed by learners in financial mathematics are not due to deficient mastery of prerequisite skills, facts and concepts.

RESEARCH METHODOLOGY

The study was guided by the positivist paradigm, which included the use of a quantitative approach for the measurement of data in order to discover and confirm causes and effects of errors committed by learners in financial mathematics. The selection of the case purposively included one East London district school; Grade 10 Mathematical Literacy learners, however, the respondents were selected using a simple random sample technique. The researcher considered the accessibility, travel costs and the time frame when choosing this particular school. The researcher ensured that each member of the sample had an equal chance of being selected and the selection of each member was independent of the selection of the next. Readily available class lists from the research site, learners' names were coded (i.e. each name was assigned a 3-digit code such as 000), were used by the researcher to select randomly 105 respondents from the list.

Sample size (n) and justification

This school had five Grade 10 ML classes with 186 learners. There were 104 girls and 82 boys with ages ranging from 14 to 18 years. The researcher adopted the simplified formula by Yamane cited in Israel (2009: 11) for proportions to determine the sample size (n), where e is the level of precision.

$$n = \frac{N}{1 + N(e)^2}$$

Hence the sample size (n) was nearly 105 where, N=186 was the population size and assuming that confidence level is 95% and the level of precision is 0.5.

Data-collection methods

Data were collected by means of structured-interview questionnaires and documentary studies (examiners' reports and other documents on the subject published by the DBE). The documentary analysis was guided by an inquiry on: (1) why do learners commit errors on given tasks in financial mathematics? and (2) errors were due to deficient mastery of prerequisite skills, facts and concepts.

Data-collection instruments

A structured-interview questionnaire was used which is a content-based questionnaire where respondents are expected to work out financial mathematics problems and one set which includes the possible underlying factors related to the different types of errors learners commit. The second questionnaire with rating scale questions using a Likert scale was used to find the underlying reasons as to why learners commit error from the respondents (Grade 10 ML learners of the participating school in the East London district).

Data analysis

In the first questionnaire which is content based, the researcher was guided by the Newman's error analysis in content analysis and identification of errors committed. Quantitative analysis with descriptive statistics, which describe the distribution, the relationship among variables and variability through the use of frequencies was used to analyse the second questionnaire. Statistical Package of Social Sciences (SPSS) version 21 was used for correlation coefficient analysis to measure the relationship between variables of each of the aforesaid research questions. Analysis of Variance (ANOVA) was used for testing the hypotheses of the study. In the data-analysis stage, the researcher avoided the TYPE I and / or TYPE II errors by presenting the data without misrepresenting its meaning. That shows that validity of the study cannot be achieved through tests only but when the results of different tools (i.e. two sets of questionnaires) are analysed concurrently.

RESULTS

Content analysis

A content-based questionnaire afforded the respondents an opportunity to work out financial mathematics problems. From a number of questions the respondents illustrated a number of approaches, some are illustrated below citing some errors identified.

1. If R12 000 is invested at 9.5% simple interest per year, calculate the value of the investment after 4 years and three months.

Figure 1:
Response of learner 1

The image shows handwritten work for a financial mathematics problem. The learner calculates 9.5% of R12,000 as R1140, then incorrectly adds 4 to this result to get R1144. Finally, they add the original R12,000 to R1144 to get a total of R13,144. The work contains several errors: using addition instead of multiplication for the interest calculation, and adding the principal to the interest instead of multiplying the principal by the total factor (4.25).

$$\begin{aligned}
 9.5\% \text{ of } R12000 &= \frac{R12000 \times 9.5\%}{100} \\
 &= R1140 \\
 \text{The simple interest in 4 years} &= R1140 + 4 \\
 &= R1144 \\
 \text{Total interest} &= R12000 + R1144 + R1144 \\
 &= R14284
 \end{aligned}$$

Learner 1 worked out 9.5% of R12 000, then added 4 to the answer instead of multiplying by 4 but even though the period of investment was 4 years and 3 months not 4. Learner 1 should have multiplied by 4.25 as the period of investment is 4 years 3 months. Calculated total interest was then added to the invested amount which was R12 000 in this regard. Elbrink (2008) classifies this type of error as a *calculation error* as the learner mistakenly used addition instead of multiplication. Nolting (1998) classifies this type of error as a *procedural error* as the learner employed incorrect steps.

Figure 2:
Response of learner 2

$$\begin{aligned}
 A &= P(1+i)^n \\
 A &= R12000(1 + \frac{9.5}{100})^4 \\
 A &= R17251.93141 \\
 A &= R17251.93X
 \end{aligned}$$

Learner 2 used a compound interest formula instead of the simple interest formula as the question required. The value of n was incorrectly calculated 4 years 3 months was supposed to be calculated as $4\frac{3}{12}$, which is 4.25 when written as a decimal. Therefore the value of n in this regard is $4\frac{3}{12}$ or 4.25, and not 4 as it is illustrated in Figure 2.

Figure 3:
Response of learner 3

$$\begin{aligned}
 A &= P(1+i)^n \\
 A &= R12000(1 + \frac{9.5}{100} \times 4)^3 \\
 A &= R31536.864X
 \end{aligned}$$

Learner 3 used the relevant formula but substituted an incorrect value of n , calculated 9.5% of R12 000, multiplied the answer by 4 and missed the fact that the period of investment was 4 years 3 months. Learner 3 committed the similar error as learner 2.

Learner 2 used the formula $A = P(1 + in)$ but then incorrectly substituted the values, which is according to Elbrink (2008) classified as the *calculation error*. The learner substituted the value 4 for n , and this can also account for *procedural error* as *incorrect steps* were followed and *missing steps* identified. The errors identified in the aforesaid learner responses can be classified as *errors due to deficient mastery of prerequisite skills* as learners were introduced to the use of formula in the previous grades (i.e. Grades 8 and 9).

Incorrect association is justified by the use of incorrect steps, where learners add instead of multiplying. The incorrect steps might be attributed to the threshold concept where learners had been taught a particular method and tended to use it even in irrelevant situations.

2. How long will it take R5 100 invested at 9% simple interest per year to yield an amount of R7 854?

Figure 4:
Response of learner 4

$$\begin{aligned}
 A &= P(1+i) \\
 R7854 &= R5100(1 + \frac{9}{100}) \\
 \frac{R7854 - R5100}{R5100} &= \frac{R2754}{R5100} (1.09) \\
 1.54 \times 1.09 &= 1.7
 \end{aligned}$$

Learner 4 wrote an incomplete formula, even though the learner substituted the formula correctly, but there was a missing component in the formula. The learner was required to determine how long it would take the invested amount to yield a given value (i.e. find the value of n).

Expected correct solution

$$A = P(1 + in)$$

$$R7\ 854 = R5\ 100(1 + \frac{9.5}{100} \times n)$$

$$\frac{R7854}{R5100} = 1 + 0.09 \times n$$

$$1.54 - 1 = 0.09 \times n$$

$$\frac{0.54}{0.09} = n$$

$$6 = n$$

Therefore it will take 6 years for the invested amount to yield R7 854.

When comparing the method used in the expected solution it is clear that the learner did not write the formula correctly, and as such could not obtain the correct answer. This type of error could be classified as an error due to incorrect association or rigidity of thinking. The fact that a component of the formula was missing would be classified as a missing step error.

3. Calculate the value of R9 700 invested at 9.5% per annum compound interest for a period of 3 years.

*Figure 5:
Response of learner 5*

$$A = P(1 + i)^n$$

$$A = R700(1 + \frac{9.5}{100})^3$$

$$A = R2735,44404$$

$$A = R2735,44$$

In answering the aforesaid question, the respondent illustrated errors attributed to their prerequisite skills, facts and concepts that were gained in the previous grades. The majority of the respondents used the formulae in working out the simple and compound interest problems. The formulae were drawn from the previous knowledge as the use of formula is not encouraged by the teaching and learning

programme of the Curriculum and Assessment Programme Statements (CAPS).

Some would use the formula and arrive at the correct answer but some would use the incorrect formula but then arrive at an incorrect answer. Others would use the correct formula but incorrectly substitute the formula and as a result arrive at an incorrect answer. The use of the correct formula could not guarantee the correct answer as some learners would not round off correctly, as the final answer is supposed to be rounded off to two decimal places. Only 31.4% of the learners admitted to always rounding off the final answer to decimal places, but 10.5% of the learners admitted they had never rounded off their final answer. About 2% of the research sample admitted to forgetting to write down the correct answer as displayed by the calculator and that indicated negligence.

Based on the analysis of questionnaire 2 where frequencies on each variable, it could be established that very few learners (24.8%) from the sample agreed to sometimes forgetting to read the instructions but about 49.5% of them maintained that they sometimes rounded off the answer to 2 decimal places whereas 31.4% claimed to always round off the final answer to 2 decimal places. About 56.2% of the sample asserted that they rounded off but incorrectly, with 5.7% declaring that they always committed such an error. About 20.9% of the respondents claimed to forget to write down the correct answer as displayed in a calculator when it was used.

Correlation analysis

Correlation among the different variable related to the reasons as to why learners commit errors in financial mathematics was tested and the SPSS output is illustrated in Table 4. The Pearson correlation and significance (p-value) of the four variables of the underlying factors related to errors due to deficient mastery of prerequisite skills, facts and concepts are illustrated in the subsequent table.

Table 4:
The correlation analysis of each variable of underlying factors related to errors due to deficient mastery of prerequisite skills, facts and concepts

		A	B	C	D
A	Pearson Correlation	1	.146	.305	.119
	Sig. (2-tailed)		.182	.002	.281
B	Pearson Correlation	.146	1	.137	.035
	Sig. (2-tailed)	.182		.455	.726
C	Pearson Correlation	.305**	.137**	1**	.208**
	Sig. (2-tailed)	.002	.455		.019
D	Pearson Correlation	.119	.035	.208	1
	Sig. (2-tailed)	.281	.726	.019	

NOTE: the variables of research question 4 were labelled A - D for the writer's convenience in constructing the following table which summarises the correlation and the significance of the stated variables.

A – I forget to read instructions

B – I do not round off the answer to 2 decimal places

C – I do round off but incorrectly

D – I do not write the answer as shown on a calculator

The correlation analysis was conducted to examine the relationship between learners forgetting to read the instructions (A) and learners rounding off answers to 2 decimal places (B), and the results were non-significant and illustrated by a weak correlation, as $p > .05$ ($r = +.15$). The relationship between learners forgetting to read the instructions (A) and learners forgetting to write down the answer shown by the calculator (D) was not significant and a weak correlation, as $p = .281$ ($r = +.12$). The relationship between learners rounding off answers to 2 decimal places (B) and learners rounding off but incorrectly (C) illustrated non-significant results and a weak correlation, where $p = .455$ ($r = +.14$).

The correlation analysis was conducted to examine the relationship between learners forgetting to read the instructions (A) and rounding off but incorrectly (C), was significant, as $p < .01$ ($r = +.31$) but illustrated a weak correlation between the aforstated variables.

The correlation analysis between learners rounding off answers to 2 decimal places (B) and learners forgetting to write down answers shown by the calculator (D) revealed non-significance, $p = .726$ ($r = +.04$) but illustrated a moderate correlation between the variables.

Examining the relationship between learners rounding off but incorrectly (C) and not writing answers as shown by the calculator (D) revealed significance, where $p < .05$ ($r = +.21$) which illustrated a weak correlation between the two variables.

The correlation analysis was conducted to examine the relationship between learners forgetting to read the instructions (A) and learners rounding off but incorrectly (C). The analysis was significant, $p = .002$ ($r = .31$).

Analysis of Variances

Significance of four variables of research hypothesis was tested using a one-way ANOVA test where the results were illustrated in tables showing the degree of freedom and the levels of significance (p-values) of each variable.

Table 5:
I forget to read the instructions

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	4.113	3	1.371	1.652	.182
Within Groups	83.849	101	.830		
Total	87.962	104			

Learners forgetting to read the instructions proved not to be significant, as $F(3,101) = 1.652$ and $p = .182$ ($r = .31$). This indicates that forgetting to read the instructions cannot be related to the aforesaid hypothesis.

Table 6:
I do not round off the answer to 2 decimal places

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2.185	3	.728	.878	.455
Within Groups	83.777	101	.829		
Total	85.962	104			

Learners not rounding off the answer to 2 decimal places did not have any significance on errors committed in financial mathematics, ANOVA illustrated, $F(3,101) = .878$ and $p = .455$ ($r = .20$).

Table 7:
I do round off but incorrectly

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	8.751	3	2.917	3.470	.019
Within Groups	84.906	101	.841		
Total	93.657	104			

Analysis of the hypothesis through the ANOVA test illustrated a significance, where $F(3,101) = 3.470$ and $p = .019$ ($r = .31$), revealed less than 5% Type II error. That indicated that there is an effect of learners doing rounding off but doing so incorrectly impacting upon the type of errors learner commit in financial mathematics.

Table 8:
When using a calculator I forget to write down the correct answer

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2.860	3	.953	1.292	.281
Within Groups	74.531	101	.738		
Total	77.390	104			

The aforesaid variable does not have any effect on the hypothesis and that was revealed by the ANOVA test results which indicate that 'learners forgetting to write down the correct answer when using a calculator' was not significant, $F(3,101) = 1.292$ and $p = .281$ ($r = .21$).

Assumption test

Skewness and the Standard deviations were used to test the Normality and Homogeneity assumption.

Table 9:
Descriptive statistical analysis of variables of errors due to the deficient mastery of prerequisite skills, facts and concepts

	N	Std. Deviation	Skewness	
	Statistic	Statistic	Statistic	Std. Error
I forget to read the instructions	105	.920	.915	.236
I round off the answer into 2 decimal places	105	.909	-.899	.236
I do round-off but incorrectly	105	.949	-.328	.236
When using a calculator I forget to write down the correct answer	105	.863	1.089	.236
Valid N (listwise)	105			

ANOVA results in testing the aforesaid hypothesis, one variable 'forget to read the instructions' illustrated a significance level where $p < .05$. All the other variables illustrated significance levels where $p > .05$ which indicated non-significance to the research hypothesis. Based on the illustrated results I had to drop the alternative hypothesis and accept the null hypothesis. I then concluded that the errors learners commit in financial mathematics are not due to the prerequisite skills, facts and concepts.

Table 10:
Identified learner errors and the associated underlying factors

Question No.	Identified errors	Underlying factors of the identified errors
1.	Use of incorrect formula: $A = P (1 + in)$ instead of $SI = P \times I \times n$ as the question required calculation of simple interest	Application of irrelevant rules or strategies
2.	Use of incorrect formula: $A = P (1 + in)$ instead of using formula: $A = P (1 + i)^n$ as the question required calculation of compound interest	Incorrect association or rigidity of thinking

Question No.	Identified errors	Underlying factors of the identified errors
3.	Use of the correct formula but the components of the formula incorrectly substituted	
4.	Could not comprehend the meaning and effect of the question to the relevant formula	Language difficulties
5.	Employed a relevant formula but could not substitute the components correctly	Deficient mastery of prerequisite skills, facts and concepts

DISCUSSIONS

From the aforesaid correlation analysis there was a relationship between learners forgetting to read the instructions and rounding off incorrectly. There was a reasonable confidence that the relationship may be stronger also in another research population. Rounding off correctly and not writing the answer as shown by the calculator also illustrated a degree of confidence with a probability of 5% errors when tested in another research population.

From the four pairs of variables two proved to be significant and illustrated weak correlations. Therefore 50% of the variables showed a correlation and significance to the tested research hypothesis.

All the above displayed variables indicated a weak correlation. This could be predisposed by a number of factors such as the sample size, sample distribution, the relevance of the questions and/or the respondents' interpretation of the questions.

The types of errors that are related to the aforesaid underlying factors include the deficits in content and problem-specific knowledge for successful performance in mathematical tasks. This is attested by ignorance of algorithms, inadequate mastery of basic facts, application of incorrect procedures and insufficient conceptual understanding. Learners did not admit to sometimes forgetting to read the instructions. Only 24.8% admitted to that. The majority of the learners (63.8%) never forgot to read the instructions.

Based on the results of the study learners always remembered to round off the final answer to 2 decimal places. Only a few ($n = 11$, 10.5%) never rounded off their final answer. Even though they rounded off their final answer, many ($n = 53$, 50.5%) sometimes rounded off incorrectly.

The majority of the respondents claimed they never forgot to write down the correct answer when using a calculator.

The following errors were identified by content analysis:

- The use of formula: learners were not encouraged to use any prescribed formula for both simple and compound interest. Due to previously acquired knowledge, learners would recall previously taught formulae and employ those to calculate simple and compound interest. Herein the enhanced threshold concept proved to be irreversible as described previously. Learners would use the formula but incorrectly. They would use a formula to find a final amount (A) when asked to find simple interest (SI).
- ignorance of algorithms, incorrect procedures in applying mathematical techniques, and insufficient knowledge of necessary concepts and symbols. Learners also forget to read the instructions and rounding off incorrectly.

- When the correct formula was used, the components of the formula were incorrectly substituted. This could be associated with a number of factors such as a lack of working memory as the learner needed to remember intermediate products of calculations and the sequence of steps to be followed in order to arrive at the appropriate answer.

On the basis of the identified errors through the content analysis and as noted by Newman's Error Analysis technique, there are reasons that underlay the difficulties students experience with mathematical problems. Indeed teachers need to determine where misunderstandings occur (Elbrink, 2008; Ratadz, 1979; Tshabalala, 2012; Riccomini, 2005; Brodie, 2005; Nolting, 1998; Department of Education, 2005; Cathercole et al. cited in Soendergaard & Cachaper, 2008). Once the direction of misunderstandings is identified, there is the need to provide directions for where effective teaching and learning strategies could be devised to overcome learners' errors (White, 2010).

In the previous grade learners were introduced to the use of formula when working out some mathematical problems. Learners rounding off but incorrectly showed significance with a moderate correlation to learners forgetting to read the instructions. In using Polya's approach through; (1) understanding the problem; (2) devising a plan; (3) carrying out the plan; and, (4) looking back through the learner; the following were the underlying factors related to the errors that due to deficient mastery of prerequisite skills, facts and concepts:

- Learners rounding off but incorrectly showed significance with a moderate correlation to learners forgetting to read the instruction.
- Learners not writing answers as shown by the calculator illustrated significance with a weak correlation to learners rounding off but incorrectly.
- Learners forgot to read the instructions; this could be related to the fact that they felt rushed in tests, or to language difficulties.
- When required to round off the answer; they did round off but incorrectly. Rounding off is supposed to be acquired and mastered earlier in their school years.
- When using a calculator they incorrectly transcribed the value displayed by the calculator. A relationship with rounding off incorrectly was revealed by the correlation test.

Meyer & Land (2006) noted the need for core concept and conceptual building block that progress understanding of subject. The authors argue that it has to be 'understood, but it does not necessarily lead to a qualitative view of subject matter' (Meyer & Land, 2006: 4). Following the data from the current data, the work of Newman (1983), Polya (1945), and Meyer & Land (2006), it appears though that learners acquired those prerequisite skills, but they showed no mastery of those skills. It is evident because learners sometimes used an incorrect formula, substituted the formula incorrectly and rounded off the final answer incorrectly.

CONCLUSIONS

Error analysis may be incorporated in the teacher training curriculum as it will assist in reducing or eliminating learner errors. It will assist educators to be able to identify learner errors, assist learners in eliminating those errors and encourage learners to review the work before submission. Understanding learners' rationale when going through their work can, also assist teachers to institute remedial lessons. Educators need to incorporate error analysis in their lesson designs, as knowledge of why learners commit errors is valuable to the educators as it will help strategies. Learners should be taught to apply Polya's problem-solving techniques. That will train them in applying the techniques to make sure they understand the question before they attempt to answer it; to plan before answering; to answer then review.

RECOMMENDATIONS

Further research studies could be conducted in error analysis in financial mathematics but the focus should be on higher grades (Grades 11 and 12) as learners continue to commit these kinds of errors even in those grades. The study population could be increased where a number of schools could be involved (five or more schools) to increase the extent to which the research findings could be generalised. Error analysis is a topic that has not yet been researched much in South Africa especially in both Mathematics and Mathematical Literacy. More studies need to be conducted so it can provide recommendations to assist educators in their lesson designs in order to assist learners in avoiding the identified errors. This could lead to the increase in learner performance in Mathematics and Mathematical Literacy.

REFERENCES

- Brodie, K. (2005) 'Using cognitive situative perspective to understand teacher interaction with learner error' *Proceedings of the 29th Conference of the International Group for the Psychology of Mathematics Education 2* pp.177-184.
- Department of Education. (2005) *National Curriculum Statements: Mathematical Literacy Grade 10-12*. Republic of South Africa, Pretoria.
- Department of Basic Education. (2011) *Curriculum and Assessment Policy Statements (CAPS)*. Republic of South Africa, Pretoria.
- Elbrink, M. (2008) 'Analyzing and addressing common mathematical errors in secondary education' *B. S. Undergraduate Mathematical Exchange* 5(1) pp.2-4.
- Goswami, U. (2008) 'Principles of Learning, Implications for Teaching: A Cognitive Neuroscience Perspective' *Journal of Philosophy of Education* 42(3) pp.381-399.
- Hodes, A. (1972) *Encounters with Martin Buber*. London: Allen Lane/Penguin.
- Israel, G.D. (2009) Determining the sample size. Program Evaluation and Organisational Development. IFAS, University of Florida. PEOD-6.
- Khan, S.B. & Chishti, S. (2011) 'Learners' errors: supporting learners for participating in Mathematics classroom' *International Journal of Academic Research* 3(1) Part II pp.655-658.
- Meyer, J.H.F. & Land, R. (2006) 'Threshold Concepts and Troublesome Knowledge 1 – Linkages to Ways of Thinking and Practising' In C. Rust (Ed.) *Improving Student Learning – Ten Years On*. Oxford: OCSLD.
- Murray, H. (2012) 'Problems with Word Problems in Mathematics' *Learning and Teaching Mathematics* 13 pp.55-58.
- Newman, M.A. (1983) *Strategies for diagnosis and remediation*. Sydney: Harcourt Brace Jovanovich.
- Nolting, P.D. (1988) 'The Investiture Controversy' *Church of the Lutheran Confession* 28(4) pp.22-30.
- Polya, G. (1945) *The Four-step Problem-solving Process*. <http://home.comcast.net/~mrtwhs/mash/polya.pdf> (Accessed 24 May, 2012).

Radatz, H. (1979) *Journal for Research in Mathematics Education*, National Council of Teachers of Mathematics. <http://www.jstor.org/stable/748804> (Accessed 20 July, 2011).

Riccomini, P.J. (2005) Identification and remediation of systematic error patterns in subtraction' *Learning Disability Quarterly* 28(3) pp.1-10.

Soendergaard, B.D. & Cachaper, C. (2008) 'Teaching Mathematics effectively to primary students in developing countries: Insights of Neuroscience and Psychology of Mathematics' *GPE Working Paper Series on Learning* 2(5) pp.11-18.

Tshabalala, L. (2012) 'Exploring Language Issues in Multilingual Classroom' *Learning and Teaching Mathematics, A Journal of AMESA* 13(6) pp.22-25.

White, A.L. (2010) 'Numeracy, Literacy and Newman's Error Analysis' *Journal of Science and Mathematics Education in Southeast Asia* 33(2) pp.129-148.

Reflections on the NCS to NCS (CAPS): Foundation Phase teachers' experiences^{1 2}

Elize du Plessis - University of South Africa, South Africa

Petro Marais - University of South Africa, South Africa

ABSTRACT

*The Curriculum and Assessment Policy Statement (CAPS) is a modification of **what** to teach (curriculum) and not **how** to teach (teaching methods) in South African schools. In July 2009, the Minister of Basic Education appointed a panel of experts (an independently constituted quality assurance body) to investigate the nature of the challenges and problems experienced in the implementation of the National Curriculum Statement (NCS). During 2011 the NCS was reviewed extensively; amendments were made to the NCS, which is now referred to as the NCS (CAPS). The aim of this study was to evaluate whether or not the amended NCS (CAPS) is an improvement on the original NCS. The Reflective Model of Gibbs and the Appreciative Inquiry Theory were used as theoretical frameworks. A qualitative research approach was used and 16 Foundation Phase teachers were interviewed to determine their views on the differences between the NCS and the NCS (CAPS). The main results indicated that implementation of the amended NCS (CAPS) remains a challenge.*

Keywords: Appreciative Inquiry Theory, Curriculum and Assessment Policy Statement, Foundation Phase teachers, Qualitative research, Reflective Model

INTRODUCTION

Worldwide governments are confronted by the challenges of curriculum change to meet regional, national and global needs (Pienaar & Raymond, 2013). The question may be asked, why another change is needed to the NCS in the form of a Curriculum and Assessment Policy Statement NCS (CAPS) (further referred to only as CAPS)? Is it because of a recent report published by the World Economic Forum (WEF) which has ranked the quality of South Africa's mathematics and science education last out of 148 countries (Wilkenson, 2014)? Poor results were also highlighted by Lekota (2014) when he described the quality of South African school education as mediocre. This statement was made after the announcement of the poor 2013 matric pass rate by Basic Education Minister Angie Motshekga. According to the Department of Basic Education (DBE), CAPS is not a new curriculum, but an amendment to the National Curriculum Statement (NCS). It, therefore, still follows the requirements of the same process and procedure as the NCS

1 Date of submission 9 October 2014

Date of Acceptance 14 May 2015

2 We wish to thank Dr Alena van Schalkwyk, our former colleague of Curriculum and Instructional Studies at UNISA for her valuable contributions; Ilze Holtzhausen de Beer, Language Editing Department of UNISA, who edited this article and the teachers' willing participation in this research.

Grades R – 12 (2002) (Pinnock, 2011). The amendments were made to address four main concerns with regard to the NCS, as identified by the task team and reported in October 2009 to the Minister of Basic Education (Department of Basic Education, 2009). These four concerns were:

1. complaints about the implementation of the NCS
2. teachers who were overburdened with administration
3. different interpretations of the curriculum requirements
4. underperformance of learners.

The debate about CAPS is whether this is a curriculum amendment, repackaging or re-curriculation. If accepted that the NCS is being repackaged, it must be in a manner more accessible to teachers and for every subject in each grade. It is important to have a single, comprehensive and concise CAPS that will provide details on what content teachers ought to teach and assess founded on a grade-by-grade and subject-by-subject basis. These will include clearly delineated topics for each subject as well as recommended number and type of assessments per term. This means then that CAPS is an adjustment to what to teach (curriculum) and not how to teach (teaching methods). These adjustments will be evaluated in this research.

RESEARCH PROBLEM

The researchers visited student teachers who were adhering to work-integrated learning, also known as teaching practice sessions at schools. The researchers learned from the mentor teachers as well as the student teachers that they experienced the implementation of CAPS as negative. Although many teachers received training with regard to the implementation of CAPS, they still struggle to appreciate the value thereof and some of them preferred the previous NCS. It was this concern that motivated the researchers to ask the following question: What are Foundation Phase teachers' perceptions and experiences of the amended NCS (CAPS)?

BACKGROUND TO THIS INVESTIGATION

There are different ways in which governments control curriculum decision making. Many countries have a highly centralised education system (Kuiper, Van den Akker, Letschert & Hooghoff, 2009). At government level a defined curriculum contains detailed regulations for objectives and learning content, school time, selection of educational materials, teaching standards and assessment. Currently there is little room for curricular input by schools and teachers. There have however, been periodic shifts and movements in curriculum policy towards either a more or less central or decentralised control in most countries (Kuiper et al., 2009).

Both forms of curriculum policy have strengths as well as weaknesses (Fullan, 2008; Hargreaves & Shirley, 2009). A centralised, detailed, prescriptive curriculum presents a clear view of the desired results and there is a perception that in practice it offers better learning results than a decentralised model does. However, the sustainability of achieving these improved learning results is a very complex matter.

In South Africa there is a centralised curriculum decision body. Without going into depth about educational and curriculum changes since 1994, we want to focus on teachers' perceptions and experiences whether CAPS (the amended National Curriculum), is an improvement on the original NCS or not.

In July 2009, the then Minister of Basic Education, appointed a panel of experts to investigate the challenges and problems experienced in the implementation of the NCS. Their task included compiling recommendations designed to improve the implementation of the NCS. The Minister's brief was in

response to written and verbal comments from a range of stakeholders such as teachers, parents, teacher unions, school management and academics, on the implementation of the NCS. There has been positive support for the implementation of the Revised National Curriculum Statement (RNCS) or the NCS, but there has also been considerable criticism of various aspects of its implementation, e.g. manifesting in teacher overload, confusion, stress and widespread learner underperformance in international and local assessments. 'While several minor interventions have been made over time to address some of the challenges of implementing the curriculum, these changes did not have the desired effect' (UMALUSI, 2014: 11).

The report of the panel presented an understanding of the context, nature and causes of these pressure points. The Minister and the Department of Education (DoE) (now DBE) was presented with a five-year plan to improve teaching and learning via a set of short-term interventions aimed at providing immediate relief and new focus points for teachers. It also included medium and longer-term recommendations to achieve real improvement in learners' education within a five-year period.

Furthermore, the panel worked closely with the Deputy Directors General for the General Education and Training (GET) and Further Education and Training (FET) branches from the then DoE to identify key areas for the investigation. The panel based their identification of problem areas on the major complaints and challenges encountered since 2002, when the NCS was introduced for the first time. The key problem areas were identified as:

- a. curriculum policy and guideline documents
- b. transition between grades and phases
- c. assessment (particularly continuous assessment)
- d. Learning and Teaching Support Materials (LTSM) (particularly textbooks)
- e. teacher support and training (for curriculum implementation).

CURRICULUM POLICY AND GUIDELINES IN SOUTH AFRICA

The panel focused specifically on the development and purpose, dissemination and support, use and availability, adequacy, clarity, accessibility and workload with regard to policy and guideline documents for the NCS. Part of this research was a comparative study done by the Council for Quality Assurance in General and Further Education and Training (UMALUSI). The word 'Umalusi' means 'shepherd' in Nguni culture, the 'shepherd' who is the guardian of the family's wealth. The responsibilities of UMALUSI are to conduct research to ensure educational quality, as well as to develop and evaluate qualifications and curricula according to the expected standard, moderate assessment to ensure that it is fair, valid and reliable, accredit providers of education and training, and verify the authenticity of certificates (UMALUSI, 2007). To improve South African curriculum development processes UMALUSI compared the South African Foundation Phase curriculum with international curricula in countries with education systems that appeared to be working well, namely Canada, Singapore and Kenya, to improve South African curriculum development processes. Dimensions of each curriculum considered included: the aims, the organising principles, the content and skills coverage and depth, the time allocation, sequencing, pacing, progression, teaching approach, assessment integration, and ease of use of the curriculum documents. The main findings were that the design of the curricula of the three countries and South Africa was very different. Kenya and Singapore represented more traditional, subject-based curricula, with no integrations. The Kenyan curriculum provided the least specification and guidance, although the focus on content made knowledge specification more detailed than that of South Africa (UMALUSI, 2011). Both Canada and South Africa stressed integration and employed an outcomes-based framework, but in different ways. The South African curriculum emphasised skills and generic learning skills, while the Canadian curriculum

specified skills but provided detailed content specifications through concept overview maps, assessment indicators and performance standards. In short, the South African curriculum lacked a sufficient coherent and systematic theory of curriculum design related to a suggested pedagogical approach or set of pedagogical principles likely to be recognised and understood by teachers within their particular social and historical content. 'The NCS did not represent a curriculum that the average South African teacher would be able to use easily' (UMALUSI, 2011: 46).

Transition between grades and phases

Regarding transition between grades and phases, questions were posed to establish whether teachers and stakeholders thought there were problems. By identifying the problem areas, the panel could determine what the nature of the problems was; and what stakeholders thought should be done about them. Particular attention was given to the transition from Grade 3 to Grade 4 and from Grade 9 to Grade 10.

Assessment

The assessment aspect of the national curriculum received the most criticism. The panel questioned what the problems were with the assessment policies; whether there was sufficient clarity and appropriate use of assessment policies and guidelines. They tried to determine what stakeholders, particularly teachers; thought should be done to address these problems.

Learning and Teaching Support Material (LTSM) and teacher support

LTSM and teacher support were two critical areas that were brought into the panel's deliberations. These two areas were the most problematic and are also critical to successful curriculum implementation.

Challenges identified, suggested solutions and recommendations

An important finding of the panel review was that there is no clear, widely communicated plan for the implementation and support of the NCS. Many teachers and parents complained that they had no vision of the 'bigger picture' in terms of what education and the curriculum set out to do and achieve, specifically with regard to the learners of South Africa. Coupled with poor learner performance in local and international tests, this has led to pockets of distrust in the education system.

Recommendation: A clear, coherent, easily understood five-year plan to improve teaching and learning across the schooling system needs to be developed and adhered to; it must also be widely communicated to the nation. Offering support to teachers and the improvement of learner performance must be its central themes. Mechanisms to monitor implementation of the plan, through regular external monitoring to assess whether it has the desired effect on learner and teacher performance, need to be built into the plan (Department of Basic Education, 2009).

Implementation dates of CAPS

The following implementation dates were proposed by the DBE for the different phases:

- The Foundation Phase (Grades R–3) and Grade 10 (FET) were implemented in January 2012.
- The Intermediate Phase (Grades 4–6) and Grade 11 (FET) were implemented in January 2013.
- The Senior Phase (Grades 7–9) and Grade 12 (FET) were implemented in January 2014.

Although CAPS only amended the original NCS, there have been some major changes that should be noted. This research will address some issues related to these major changes in the Foundation Phase.

NCS to NCS (CAPS): main changes

- CAPS Foundation Phase: instructional time will increase

- Numeracy will now be called Mathematics, and Literacy will be called Language
- First Additional Language will be added to the Foundation Phase (one language must be the Language of Learning and Teaching (LoLT))
- All grades will use a 7-point scale
- Learning outcomes and assessment standards have been removed (general aims) and are now called *topics* (content/themes) and *skills*
- Learning areas and learning programmes are now called *subjects*
- CAPS gives a week-by-week teaching plan
- Curriculum statements and learning programme guidelines are set out in one amended document called CAPS (Department of Basic Education, 2011).

Against this background two theoretical frameworks are especially significant and important for the interpretation of the findings of this research.

THEORETICAL FRAMEWORKS

Two theoretical frameworks were used as a sounding board for data analysis of this research project. The researchers used these two theories to analyse and interpret data by focusing on both the positive and negative aspects and to use both aspects to make recommendations at the end. The first theoretical framework used as an epistemological guide to account for the knowledge that is produced in this study is the Gibbs Reflective Model (Gibbs, 1988). Reflectivity, according to Gibbs, is applicable understanding and thinking about a phenomenon. The Reflective Theory focuses on constantly gathering evidence about how effective or worthwhile actions are analysed, in order to learn from the experience. Thus, by reflecting on NCS and CAPS, evidence on the effectiveness of both curriculum models may be provided. Gibbs' (1988) reflective cycle encourages a clear description of the situation, analysis of feelings and evaluation of the experience, to make sense of the experience and conclusion where other options are considered. Two of the principles of Gibbs' Reflective model focus on description and evaluation – principles that tries to understand what is happening at the moment and what was good and what was bad about the experiences. Questions like: 'How well did things go?' and 'Were things satisfactorily resolved?' may be asked. These principles were applied to the participants' positive and negative experiences regarding the amendment of NCS to CAPS.

The second theoretical framework, Appreciative Inquiry Theory, is particularly suitable within the area of education. Appreciative Inquiry practitioners based their methods on the initial set of four principles (Cooperrider & Srivastva, 1987) which stated that inquiry into the social potential of a social system should begin with appreciation, should be collaborative, should be provocative, and should be applicable. The original method called for a collective discovery process using 1) grounded observation to identify the best of what is, 2) vision and logic to identify ideals of what might be, 3) collaborative dialogue and choice to achieve consent about what should be, and 4) collective experimentation to discover what can be. This theory is thus based on the postmodern constructionist theory namely that reality (curriculum change in this instance) is socially constructed. Appreciative Inquiry is a shift from looking at problems and shortages, by focusing on strengths and successes. It is a positive approach to organisational change. It is the cooperative search for the best in organisations, and involves the art and practice of asking questions to heighten positive potential. White (1996) says appreciative inquiry focuses on the positive aspects of a phenomenon in order to try to correct the negative. Appreciative Inquiry, which is a set of principles and beliefs about how organisations and systems function, attempts to support organisations to focus on their values, visions, achievements and best practices.

Hammond (2002: 23) identifies *inter alia* two basic assumptions of Appreciative Inquiry. The first assumption can be summarised as follows: societies, organisations and groups (the school) believe that what we focus on becomes our reality. This reality (curriculum change) is created in the moment, and there are multiple realities. Another assumption is that people have more confidence and comfort in their journey to the future when they carry forward positive parts of the past. Both positive and negative teaching experiences in the past are likely to be carried into the future. Appreciative Inquiry, according to Cooperrider, Whitney and Stravros (2003: 29), is a collaborative effort to explore 'positive and negative aspects of reality' (curriculum change) by encouraging and supporting their positive experiences.

RESEARCH METHODOLOGY

An exploratory research design was used. Two main characteristics of exploratory research are that it has a basic research goal and researchers frequently use qualitative data (De Vos, Strydom, Fouche & Delport, 2011). These two characteristics are applicable to this research. The researchers wanted to gain insight into a specific situation namely, the perceptions of teachers regarding the curriculum change from NCS to CAPS, and therefore they viewed an exploratory research design useful (De Vos et al., 2011).

A qualitative approach was used. Individual interviews were conducted with 16 teachers teaching in the Foundation Phase, as CAPS was implemented in the Foundation Phase in 2012. The sample of the 16 participants was taken from two rural and two urban primary schools in Gauteng; two rural primary schools in Mpumalanga; two urban primary schools in North West and 2 urban primary schools in KwaZulu-Natal. Two teachers from each of the above mentioned schools were interviewed. These provinces are all in South Africa and were targeted for the research as the researchers had to visit student teachers doing their teaching practice in these schools. Therefore, the areas were determined by the student teachers' placement arrangements. The participants are all mentor teachers for the student teachers. A prerequisite for the participants was that they had to be teaching for five or more years. The reason for this was that the researchers needed the views of participants who have teaching experiences with regard to NCS as well as CAPS. The following research questions for the comparative analysis of NCS and CAPS were asked:

1. What were your positive perceptions and experiences of NCS? Motivate
2. What were your negative perceptions and experiences of NCS? Motivate
3. What would you consider valuable about CAPS? Motivate
4. What are your concerns about CAPS? Motivate
5. Do you think the repackaging of NCS to CAPS had more advantages than disadvantages with regard to content, assessment and skills which learners are expected to acquire and teachers to teach? Motivate
6. Do you think CAPS provides efficient guidance to teachers?
7. What suggestions do you have that can promote teaching and learning with CAPS?

Data collection was done by means of individual interviews, making use of semi-structured and open-ended questions. Coding was done as part of content analysis in three phases according to the questions set in the interview schedule. In the first phase keywords in the data received for each question were identified in order to organise the data. In the second phase the keywords in the data of every question were clustered into categories and in the third phase categories were consolidated into themes for every question in the interview schedule. The researchers did their best to evade bias by using different tactics, such as a maximum variety of participants, using multiple researchers and returning to interviewees when there was a lack of clarity about meanings. The researchers also resorted to continuous self-monitoring. Analysis of the data led to the findings presented below. The researchers aimed at reporting the participants' viewpoints, thoughts, intentions and experiences accurately by making use of direct quotations in the findings.

Ethical measures were respected. The researchers knew that they had to be competent, honest and adequately skilled to undertake the research. The research was conducted in an ethically truthful manner as the researchers were constantly aware of their ethical responsibilities. The self-presentation of the researchers in the initial contact and interviewing was essential to gain cooperation from the participants. The latter were informed beforehand about each individual researcher and the detailed reasons for the investigation. Furthermore, participant anonymity, as well as confidentiality, was maintained at all times. Participation was not compulsory and the participants could withdraw at any time without penalty. They were invited to review the findings. They all gave their consent to participate in the interviews.

DISCUSSION OF THE FINDINGS

The findings were consolidated into the following five themes identified from the participants' perspectives, judgements, and experiences, namely (1) content, (2) assessment, (3) workload, (4) training of CAPS and (5) the implementation of CAPS. Although the findings are limited to the South African situation, other countries involved in curriculum change may also find these findings valuable.

Analysis of the data by determining the positive and negative aspects of each theme as experienced by the participants led to the following findings. The researchers aimed at reporting the participants' viewpoints, thoughts, intentions and experiences accurately, by making use of direct quotations in the findings.

Content

Positive experiences of the NCS

The positive experiences regarding NCS content as perceived by the participants were that the teachers had the advantage of planning their work and taking their time to teach a theme until they were satisfied that the learners had mastered the content. All 16 participants indicated that the NCS gave clear specifications on what had to be taught and learned on a term-by-term basis. According to the participants they had more time to work through the syllabus and had more time to accommodate individual learners. They had the freedom to teach according to the learners' needs and select themes in collaboration with the learners' interest. According to the Inquiry Theory (Gibbs, 1988) they appreciated this freedom. Furthermore, on reflection of their teaching the participants felt that these aspects contributed towards job satisfaction.

Negative experiences of the previous NCS

Certain negative perceptions regarding NCS content were conveyed by the 16 participants. They commented that the NCS was too broad and therefore not specific to what teachers had to teach as there was 'no clear structure of the curriculum'. They also experienced overlapping and repetition of content from term to term and from one grade to another. Another participant mentioned that the many learning areas were confusing. The participants agreed that a gap existed between Foundation Phase to Intermediate Phase. Content also differed between schools and between provinces for the same grade. This had negative implications for learners moving from school to school in adapting or catching up with the new work since every region and school had their own interpretation of the curriculum – especially theme-based work. Furthermore, the NCS demanded a lot of learning material to be provided for school projects and class work as there 'were too many subjects' (learning areas). In schools with poor resources the teachers struggled to teach. A general feeling among the participants was that no prescribed books also meant there was no clear indication of learning materials.

Although we looked at these negative perceptions of the NCS, the Appreciative Inquiry recommends that we take note thereof. By gathering this evidence we are able to avoid mistakes from the past and rather convert the successes of the NCS to curriculum changes in CAPS (Gibbs, 1988).

Positive experiences of CAPS

According to 10 of the participants, CAPS attempted to address some of these negative aspects of the NCS. For example, one of the participants believed that CAPS concentrated on the formal planning and preparation of the curriculum by providing structured lesson plans. This guided teachers in their teaching activities rather than leaving the teachers on their own regarding content as was the case with NCS. Time was wasted when teachers had to determine what and how to teach. With CAPS lesson plans were available for teachers and textbooks and worksheets were given to learners. One participant felt that the 'use of textbooks gives some structure' and another participant confirmed that 'many resources are available; it makes preparation and assessment easier'. By reflecting on the teachers' negative experiences, it would help them to understand these experiences better and leave them with other options to consider (Gibbs, 1988) and what can be done.

CAPS promoted same content for learners, nationally and this content could at the same time 'be contextualised according to availability or non-availability of particular resources', allowing teachers to personalise their own teaching. All 16 participants approved of the fact that CAPS gave content clarification by providing specific aims, skills and content areas, as well as recommended resources for lessons per grade. A participant said CAPS paid attention to the content and how the teachers plan, assess and teach during the time allocated for each subject. This is done by providing clear guidelines on pacing, sequencing and curriculum coverage. Hereby CAPS amended the NCS by considering other options and avoiding repetition of content in different grades and the over-emphasis of content in a grade (Gibbs, 1988). Furthermore, with CAPS implementation of the content was easier and CAPS provided more uniformity across the provinces, districts and schools. The participants applauded the fact that CAPS, by employing the Reflective Theory emphasised teaching and assessing the same content at the same time to a particular grade, unlike the NCS where everything was left to the discretion of the teacher. CAPS had the advantage of enabling all learners in the country to be taught and assessed on the same content as teachers are bound to teach what is specified per subject per term. Learners moving from a school or province can carry on from where they left off. 'This helps the learners as well as the teachers because less time is spent on catch up and more ... on the child's (learner's) needs to ... cope with change.' One of the participants also felt that CAPS addressed the issue of the learners' right to learn in their mother tongue. According to this participant 'there seems to be more emphasis on reading in Language for Foundation Phase, therefore it aims to improve the nation's literacy levels'.

Negative experiences of CAPS

The negative perception of CAPS among the participants was that it posed a challenge to the workload of learners in the Foundation Phase. A participant stated that it is 'a bit ambitious in terms of the amount of content that has to be covered each term'. This is due to the fact that each day has its own specific work. The participant is convinced that CAPS encouraged teachers to teach fast learners, leaving those who are slower to cope on their own. According to this participant this has practical implications when learners should be operating at the same level, with the same content at the same time. There is no time to cover skipped topics and, as a result, uncontrolled circumstances, like teachers' and learners' absenteeism, led to gaps and some content not being mastered. Another participant pointed out 'that there is more reliance on content rather than skills and thinking'. That basic requirements for resources were not always given or listed in all subjects, was pointed out as a shortcoming by one participant.

From these curriculum and transition changes, it is clear that according to the Appreciative Inquiry Theory, CAPS has been formulated to address the shortcomings experienced with the NCS. The NCS's shortcomings of allowing the teacher too much leeway and freedom in deciding what content to teach and when to teach it, was addressed by very specific instructions and guidelines prescribed by CAPS. At the same time the positive curriculum and transition aspects of the NCS has been further enhanced by CAPS.

Assessment

Positive experiences of the NCS

The second theme identified from the data was the question of how to assess the learners. All the participants agreed the NCS had positive aspects regarding assessment (in line with Appreciative Inquiry Theory). One participant testified that with NCS learners had the opportunity with each assessment moment to focus on exactly what was required of them and they could 'look back afterwards and establish where they had not met criteria'. Another participant stated that assessment methods were 'broad in focus' and teachers had the freedom to choose certain assessment standards and learning outcomes themselves. Four of the participants agreed that learners could help one another during group work, while project research tasks further enabled learners to learn from one another. This led to more continuous assessment, independent from test and examinations assessments. Regarding this issue, one participant remarked that a mark scaling (on a scale from 1 to 4) was user friendly and easy to use.

Negative experiences of the NCS

At the same time all the participants felt a negative aspect was that the NCS did not provide enough guidelines in the classroom for teachers on how to improve teaching, learning and assessment activities. As one participant said 'there was no clarity on passing or failing the learner'. Assessment tools were very general and there were too many assessment tasks, memoranda, recording sheets, and so forth. There were also too many outcomes to use as references, which had to be written out. This meant, according to the participant, 'too much administration with all the LOs (Learning Outcomes) and ASs (Assessment Standards) you need to know and achieve'. It was often difficult to find the right LO or AS for a particular activity. The participants experienced that the NCS lowered standards as even slow learners could progress to the new level. Generally there was 'too much emphasis on assessment, leaving insufficient time for actual teaching'. According to the Reflective Theory (Gibbs, 1988), making use of evaluation, these negative assessment experiences were addressed in the amended CAPS.

Positive experiences of CAPS

The participants' positive perception of CAPS was that it was comprehensive and very assessment-oriented. 'I think it is a good thing that formal and informal assessments, projects and investigations and assignments are planned and spread out throughout the year to continuously identify, gather and interpret the performance of the learners', as one participant summed it up. The annual teaching plan guided what teachers will teach and assess and what learners will learn. Even if it 'extends teachers and learners, it is quite specific or contracted', according to one participant. It provided better guidance to teachers, as well as assessment forms to guide the assessment process. It also guided teachers on the number of tasks for formal assessment. The available support did 'make assessment easier' for teachers and learners alike, according to one participant. By focusing on the strength of these assessment criteria, it is a positive approach to change according to the Appreciative Inquiry Theory.

Negative experiences of CAPS

Certain concerns were raised by two of the participants regarding assessment in CAPS, as they experienced a higher failure rate among the learners because of the system. One participant states 'the period is too short for the pace of the pupils' and another participant felt 'the level of the content is too high for learners'. Certain restrictions and limitations were noted by the other participant, for example the assessment was too structured and there was no leeway for the individual learning styles of the learners; assessment was also less frequent and more based on tests. The latter participant mentioned that 'in some learning areas only two assessments are needed – I feel that learners need more opportunities to get a well-deserved mark'. But mostly, by applying a positive approach, these assessment adjustments from the NCS to CAPS heightened the positive potential of these specific changes. This is supported by both the Reflective and Appreciative Inquiry theories on how organisations (schools) achieve best practices.

Workload

Positive experiences of the NCS

Nothing was mentioned by the participants.

Negative experiences of the NCS

The third theme that arose from the data was the workload involved. Six of the participants' views on the negative aspects of the NCS were clearly stated. One of the participants said that teachers had to develop work schedules and learning programmes which was a lot of work. Another participant viewed preparing lessons and involvement in other administrative responsibilities instead of teaching as 'time-consuming activities'. A third participant complained as follows: 'The paperwork for the daily planning was immense. It was cumbersome to use'. Three other participants indicated that 'keeping of portfolio files for learners' was time-consuming.

Positive experiences of CAPS

There was only one positive remark regarding the workload of CAPS. According to this participant, the Learning Standards and Assessment Standards have been regrouped, which has reduced the workload on the teacher's side. It has the aim of lessening the administrative responsibilities of teachers and ensuring that there is clear guidance and consistency for teachers when teaching.

Negative experiences of CAPS

Negative aspects regarding the workload of CAPS revolve around aspects such as more paperwork in CAPS than in NCS. More written work is needed to be done by teachers and more teaching aids are required, according to one of the participants. Another participant revealed that teachers with poor artistic skills struggled to make teaching aids. Moreover, another participant added that 'the number of topics to be completed for CAPS makes it difficult to successfully develop maths concepts and skills'.

The above-mentioned remarks of the participants prove that they agree on the heavy workload regarding both the NCS and CAPS, except for one participant who differed from the others on the workload for CAPS.

Training of CAPS

Five of the participants underlined definite positive aspects regarding CAPS training. According to them, 'teachers are well trained to implement their knowledge when teaching'. These participants were adamant that the training they received resulted in 'clearly understanding learning programmes and working schedules that guide teachers on what to teach and how to teach it'.

Regarding the negative reflections of the participants with reference to CAPS training, eleven of the participants testified that training was poor, and they were convinced that the 'lack of continuous training for teachers through workshops hinders the success of CAPS'.

The research findings provide valuable information concerning CAPS training. It is clear from the findings that a need for more training and guidance regarding implementation of CAPS was pointed out by other participants. More on-going, hands-on training is needed by teachers in order to address the dangerous gaps that still exist.

Implementation of CAPS

The fifth theme gleaned from the data deals with the participants' negative and positive experience regarding the implementation of CAPS.

Seven participants shared their positive experiences of the implementation of CAPS. They agreed that the guidelines were clear and useful and that the amended version of CAPS provided better guidance to teachers. Furthermore, the teachers were well supported by curriculum implementers. One of the participants acknowledged that 'workbooks will be provided for all learners from Grade 1 to 6. This will provide resource support for teachers'. Another participant pointed out that 'the annual teaching plan guides what teachers will teach'.

Contrary to the positive aspects, nine participants remarked negatively on the implementation of CAPS especially due to lack of training. They agreed that it was not easy to teach CAPS and therefore it is difficult to implement it. They are convinced that for CAPS to be successful it needed more thoughtful implementation. Possible additions or deletions, regarding aspects such as assessment and learning content to be mastered in one year, needed to be considered. One of the participants suggested that more school visits from curriculum implementers should be a priority to help and guide teachers to implement CAPS. According to another participant, facilitators lacked knowledge about CAPS and they imparted wrong knowledge and information to the educators. According to this participant 'you go to a workshop, you come out, still not understanding what was it about, simply because facilitators failed to deliver. Ask them questions about CAPS – they can't answer you'. Another participant added that CAPS was a 'top down implementation'. This is also alluded to by Ngubane (2014) where he stated that the DBE is tasked with leadership, policy-making and the monitoring responsibility of improving the quality of learning and ensuring quality sustained education, but fails to do it properly.

The positive and negative aspects identified in the themes that arose from the data regarding NCS and CAPS link with one of Gibbs' principles of reflective theory, namely, evaluation. This was done by making a judgement or evaluating what was good and what was bad about the experiences regarding NCS and CAPS and discussing them. Using Gibbs' principle of evaluation, this research project was able to consider what went well and what not so well. The purpose of Gibbs' principle of evaluation is therefore to make sense of, and to work on, the negative experiences. This attitude can be very valuable to address the challenges related to CAPS.

The findings are also in line with Appreciative Inquiry. Organisations and systems like the South African education system and its curriculum challenges demonstrate that what we focus on becomes our reality. This phenomenon (curriculum change) has multiple realities. The different themes that arose from the data, namely, positive and negative reflections on content, assessment workload, training support and implementation with regard to NCS and CAPS, underline the existence of multiple realities – each with positive and negative aspects.

Another assumption of Appreciative Inquiry is people's perception that they have more self-confidence when they carry forward positive and negative aspects from the past. Both positive and negative teaching experiences in the past are likely to be carried into the future. Appreciative Inquiry, according to Cooperrider et al. (2003: 3), is a joint effort to explore positive and negative aspects of reality (curriculum change) by encouraging and supporting positive experiences. It helps to discover what gives 'life' to a system (CAPS) when it is effective and functional.

Participants, suggestions to promote teaching and learning of CAPS

Six of the participants came up with the following suggestions. The training of teachers should be done on a continual basis, to assist those teachers who are not coping. The school visits by curriculum implementers should be done more regularly, to help and guide teachers on the implementation of CAPS. Schools should be provided with materials for making teaching aids. CAPS needed thoughtful implementation and possible additions or deletions – pitfalls were already pointed out in the latest UMALUSI report (UMALUSI,

2013: 1-5). The DBE should encourage independent thinking and get creative teachers to assist with training and implementation. Facilitators must be knowledgeable about the new curriculum.

CONCLUSION

To a great extent, CAPS guides what must be planned and taught against what must be assessed. It is well structured; it covers study areas, topics and sub-topics, examples, plans, annual teaching plans, assessment activities and resources to guide teachers. This means that teachers are able to plan effectively using these guidelines. Teachers are guided to use appropriate forms of assessment. Time tabling provides clear guidelines on the number of periods to be allocated for each subject. Creative teachers might find CAPS a bit restricting, especially in more forward-thinking schools. Teachers have little say in what they teach and when. Moreover, implementation and provision of textbooks remain a challenge.

This research highlighted areas that need attention by the DBE, like the amount of work that learners and teachers have to do in the Foundation Phase, provision of resources, a higher failure rate and poor performance of learners in Languages and Mathematics. South Africa does not differ from other countries, as all over the world school systems need continuously to revise, redesign and restructure. The findings of this research can, therefore, also be of value for other emerging countries involved in curriculum change.

REFERENCES

- Cooperrider, D.L. & Srivastva, S. (1987) 'Appreciative inquiry in organizational life' In R.W. Woodman & W.A. Pasmore (Eds.) *Research In Organizational Change And Development* Vol.1 pp.129-169. Stamford, CT: JAI Press.
- Cooperrider, D.L., Whitney, D. & Stravros, J. (2003) *Appreciate inquiry handbook: The first in a series of AI workbooks for leaders of change*. Bedford Heights, OH: Lake Shore Communications.
- Department of Basic Education. (2009) *Report of the task team for the review of the implementation of the National Curriculum Statement*. Pretoria, South Africa: Government Printer.
- Department of Basic Education. (2011) *National Curriculum Statement Grades R-12*, 11 September. South Africa <http://www.education.gov.za> (Accessed June 2013).
- De Vos, A.S., Strydom, H., Fouche, C.B. & Delport, C.L. (2011) *Research at grass roots* (4th ed.) Pretoria: Van Schaik.
- Fullan, M. (2008) Curriculum implementation and sustainability. In F.M. Connelly (Ed.) *The Sage handbook of curriculum and instruction*. pp.113-122. Los Angeles: Sage.
- Gibbs, G. (1988) *Learning by doing: a guide to teaching and learning methods*. Oxford: Further Education Unit.
- Hammond, S.A. (2002) *The thin book of appreciate inquiry*. Plano, TX: Thin Book Publishing Company.
- Hargreaves, A. & Shirley, D. (2009) *The fourth way: The inspiring future for educational change*. Thousand Oaks, CA: Corwin.
- Kuiper, W., Van den Akker, J., Letschert, J. & Hooghoff, H. (2009) *Curriculum policy and practices in an international comparative perspective*. Enschede: SLO.

Lekota, M. (2014) 'Quality of SA education "mediocre"' *News24*. <http://www.news24.com/Sout-Africa/Politics/Quality-of-SA-education-mediocre-2014-01-07> (Accessed 26 September, 2014).

Ngubane, M. (2014) Education in South Africa 20 years on: Quality and safety in schools remain priorities. <http://www.actionaid.org/south=africa/2014/06/education-south-africa-20-years-quality-and-safety-schools-remain-priorities> (Accessed 28 September, 2014).

Pienaar, C.F. & Raymond, E.B. (2013) 'Reflections on a shared leadership approach to curriculum development in Higher Education' *South African Journal of Higher Education*. Vol 27(5) pp.1290-2304.

Pinnock, A.J.E. (2011) *A practical guide to implementing CAPS: a toolkit for teachers, schools managers and education officials to use to assist in managing the implementation of a new curriculum*. Alexandra: NAPTOSA.

UMALUSI. (2007) *Learning from Africa: UMALUSI's research comparing syllabuses and examinations in South Africa with those of Ghana, Kenya and Zambia*. An UMALUSI research report. pp.32-33. <http://www.UMALUSI.org.za> (Accessed 24 June 2014).

UMALUSI. (2011) *All the cattle in the kraal: An overview of UMALUSI's research 2003-2011*. November 2011. An UMALUSI research report. pp.44-46. Pretoria: UMALUSI.

UMALUSI. (2013) *UMALUSI Strategic plan. Parliamentary monitoring group*. <http://www.pmg.org.za> (Accessed 31 January 2014).

UMALUSI. (2014) *What's in the CAPS package? Overview*. Pretoria: UMALUSI.

White, T.H. (1996) 'Working in Interesting Times: Employee morale and business success in the information age' *Vital Speeches of the Day*. May 15, Vol XLII (15).

Wilkenson, K. (2014) 'Is SA bottom of the class in maths and science? WEF ranking is meaningless' *Africa Check*. <http://africacheck.org/reports/is-sa-bottom-of-the-class-in-maths-and-science-why-ranking-is-meaningless/#comments> (Accessed 3 September, 2014).

Continuous assessment in Expressive Arts in Malawian primary schools¹

Grames Wellington Chirwa, University of Johannesburg, South Africa
Devika Naidoo, University of Johannesburg, South Africa

ABSTRACT

The new Curriculum in Malawi: the Primary Curriculum and Assessment Reform (PCAR) designed on the principles of integrated learning areas; outcomes; learner-centred pedagogies and continuous assessment (CA) was implemented in 2007. The purpose of this study was to investigate Expressive Arts teachers' understandings, experiences and practices of continuous assessment in a selection of six state primary schools. Within a qualitative research design, and using the concepts of 'instructional system' and 'learning milieu' of Illuminative evaluation as postulated by Parlett and Hamilton (1976), data were collected through observations, interviews and document analyses. Teachers' practices were characterised by an informal, technical form of assessment that privileged rote recall of facts and meeting bureaucratic requirements. The teachers cited large classes, lack of material resources and insufficient time as constraints. This study recommends that attention be given towards developing teachers understanding of CA principles and practice both at pre-service and in-service levels.

Keywords: Illuminative evaluation, Primary Curriculum and Assessment Reform; formative assessment, continuous assessment and summative assessment

CONTEXTUAL BACKGROUND

Let us first reflect on a typical scenario related to assessment in an average primary classroom in Malawi:

Teacher: 'Today, we will continue learning about mirroring. What did we say mirroring is?'

Children (collectively): 'It is imitating someone.'

The teacher continues to ask questions on previous concepts taught. All correct answers are acknowledged with 'good', 'well done', 'excellent' or, 'a hand clap for him/her'. For a wrong response, the teacher says, 'no', 'wrong', 'incorrect', or 'keep standing on your feet until you give a correct answer'. Next, the teacher verbally introduces the day's topic and writes it on the chalkboard. S/he then proceeds to develop the lesson. Once in a while s/he pauses to countercheck on learners' attention and understanding or gives an illustration or example. Next, the teacher gives pupils a task to work on. A few minutes later, red pen in hand, the teacher walks around and monitors the written work. S/he checks if the answers are right and

¹ Date of submission 10 October 2014

Date of Acceptance 29 August 2015

crosses off all wrong answers. If time allows, s/he or the pupils revise the work. If it was a written task, pupils write corrections. This is the main form of continuous assessment (CA) in primary schools in Malawi.

It is against this background of the prevalence of technical forms of CA practices by teachers that the government in Malawi introduced 'continuous assessment' in the new curriculum in Malawi. Continuous assessment in the new curriculum is a form of formative assessment to be integrated in the teaching and learning process.

The Primary Curriculum and Assessment Reform explains that the importance of integrating continuous assessment in the teaching and learning process is: it provides feedback on what learners have achieved and so builds up a record of each learner's progress against the primary outcomes for each learning area; it helps teachers to identify a learner's strengths and weaknesses so that they can help learners to learn and improve through remediation or enrichment support; it gives a chance to learners to assess their own performances and setting their own goals for improvement; it provides teachers with feedback about the methods and assessment techniques they use for teaching so that they can make decisions to improve their teaching; it encourages more and better communication between teachers and learners; it monitors the learners' performances to assist them to perform at their best and at their own pace rather than to pass or fail them all after a test on a specific day; it enables teachers to report regularly, through the year, to parents, officials and other interested people on the learners' performances and it provides valid indicators on the quality, relevance and effectiveness of the whole curriculum for ongoing renewal and improvement (Malawi Ministry of Education, 2009: 24).

The PCAR further explains that there are four types of tools which are to be used for continuous assessment in the new curriculum. These tools are: firstly, tools for generating achievement levels. These tools include scoring rubrics, checklists, task sheets and marking schemes. Secondly, there are recording tools. These tools include Attendance /Assessment Register; thirdly, reporting tools include Report Cards; finally, storage tools of learners' performance records include the Learner's Portfolio and the Teacher's Portfolio.

In Expressive Arts, the teacher's guide suggests strategies for presenting the lessons and assessing the learners in the classrooms. The suggested learners' assessment tasks in the Expressive Arts teacher's guides are in the form of written work or teachers observing the students as they perform the assigned tasks. Each outcome has corresponding exercises in the learners' book. All exercises in the learners' books should be attempted by all pupils so that teachers can have a clear understanding of the level of performance and hence the achievement of outcomes. Teachers are asked to ensure that learners attempt all questions in any particular exercise in order to get some degree of accuracy in the assessment. For example, the Standard 8 assessment task on the topic, 'General and personal space' reads as follows: give meanings of personal and general space; draw personal space and draw general space.

Although literature in Malawi indicates that teachers in the primary school sector face enormous constraints, Mhango (2008) observed that there are not many studies that investigated, in a crucial way, how such constraints impact on teachers' classroom practices. In this connection, Croft (2002), who studied the use of songs in English lessons of lower classes in primary schools in Malawi, argued that most of donor-funded research in the country focused on factors affecting the quality of education rather than classroom practices. She, therefore, recommended a more critical investigation of how teachers implement the school curricula. For example, she recommended that observations and discussions with teachers were critical avenues in the exploration of teachers' classroom practices. Given that to date, there are no documented studies of teachers' implementation of continuous assessment in the PCAR this study attempts to provide an ethnographic description of how CA is implemented in a selection of classrooms.

THEORETICAL FRAMEWORK

The theory of Illuminative evaluation (Parlett and Hamilton, 1976) provided a promising macro-framework for comparing theory and practice in continuous assessment. Two key components of Illuminative Evaluation are the Instructional System and the Learning Milieu. The Instructional System refers to what has been planned and written up in documents to guide teaching and learning and assessment. These documents include syllabuses, teachers' and pupils' books, and all other relevant teaching and learning and assessment guidelines materials. The 'learning milieu', refers to what teachers and learners actually do in classrooms.

Illuminative evaluation thus enables understanding of the 'gap' or 'fit' between the Instructional System and the Learning Milieu. In using Illuminative evaluation in the study, the conceptual difference between the 'instructional system' and the 'learning milieu' made it possible to compare the teachers' assessment practices in the classroom to the specifications of the instructional system.

CONCEPTUALISATION OF CONTINUOUS ASSESSMENT

The prevailing definitions of assessment by various scholars, for example, Withers (1994: 13), McMillan (1997: 8) and Ward (1980: 3), are that assessment is a process that encompasses testing, measurement and evaluation and assessment leads to decision making. More recent definitions of assessment also focus on the idea that assessment is a continuous process. For example, Salvia and Yeseldyke (1995: 26) state that 'assessment is a continuous process, performed to gain an understanding of an individual's strength and weakness in order to make appropriate educational decisions'.

A distinction is made between formative and summative assessment. The two assessments are distinguished according to their educational purposes. According to McMillan (1997: 106-107),

Formative assessment occurs during a lesson or unit to provide ongoing feedback to the teacher and student. The purpose of formative assessment is to provide correct actions as instruction occurs to enhance student learning. Formative assessment is usually integrated into the normal course of teaching and its purpose is to identify particular learners' difficulties with a view to providing appropriate subsequent opportunities for learners to develop their understandings.

This definition of formative assessment conceives of assessment as an integral part of the teaching/learning process on which the learner and the teachers' decisions about the effectiveness of the educational process can be based. Formative assessment is also referred to, by many a scholar, for example, Du Plessis, Conley & Du Plessis (2007: 66) as assessment for learning. Summative assessment on the other hand occurs at the end of a block, or period, of teaching. It aims to quantify the extent to which the learner has mastered the material that has been taught and the success of the course (Gipps, 1994). Summative assessment is also referred to, by many a scholar, for example, Du Plessis et al. (2007: 66) as assessment of learning.

The PCAR refers to McMillan's (1997) formal formative assessment as continuous assessment. Malawi Ministry of Education (2005: 3) defines continuous assessment as 'assessment in which learners have to be assessed in what they are able to do and display in each learning activity rather than assessing them at the end of the term or the year'. Continuous assessment thus differs from summative assessment in that it is conducted as the learning process takes place and is used to influence or inform the learning process. The assessment approach also involves more than one assessor. It includes teacher assessment, self-assessment and peer assessment. Some of the challenges of continuous assessment as cited by Le Grange and Reddy include:

Possible increase in both teacher and learner workload for teachers because extensive record keeping and monitoring of individual learners are required, and for learners because they are required to consciously assess their own work. When school work is done at home, the possibility of collusion among learners and assistance from experienced persons may occur and the assessment is then not an accurate reflection of the learner's abilities. Continuous assessment may be difficult to apply with large classes because it takes time to assess individual learners authentically (1998: 11).

Studies have been conducted in South Africa to explore teachers' practices of continuous assessment. For example, Van der Berg and Shepherd (2008) conducted a study on the continuous assessment practices of Grade 12 teachers in different subjects in the schools of the Western Cape.

The study found that there were inaccurate assessments mainly due to teachers' poor subject matter knowledge of the subjects they were teaching. Students were being given inflated continuous assessment marks. This gave students a false sense of security that they were well-prepared for the matric exams, thereby leading to unrealistic expectations and diminished effort. The study concludes that continuous assessment has poor reliability to contribute to decision making about selection of students to universities as well as for judging students' mastery of the national curriculum.

Adebowale (2008), conducted a study on continuous assessment practices in the Ondo state of Nigeria. The results of the study were that there is no agreement amongst teachers in terms of how regularly continuous assessment should be conducted. The researchers saw confusion amongst teachers in four areas: how often the pupils were assessed; how many of such assessment should be graded and weighted; and the lack of other assessment tools apart from cognitive tests, assignment, and examinations; and where it is practised, it is not included when the pupils' assessments are combined. The researcher recommended that simplified and concise manuals, leaflets, and handbooks be developed for distribution to teachers.

DATA COLLECTION

This article arose from a larger doctoral research project focused on studying the pedagogic and assessment practices of Expressive Arts teachers in Standards 7 and 8 classrooms. The data was collected in six schools in a period of five months, from January, 2010 to May, 2010. In all, 12 Expressive Arts teachers drawn from the six state schools in Zomba were studied. The teachers represented Standards 7 and 8 in a school. All the teachers in the study were qualified. Their teaching experiences ranged from five to 20 years. Their ages ranged from 34 to 52 years. Seven of the teachers in the study were females and five were males. All the teachers studied were trained in the normal training programme of the teaching of Expressive Arts. The school and teacher samples used in the study are summarised in Table 1 below:

*Table 1:
Summary of study schools*

School	A	B	C	D	E	F
Type	Rural	Urban	Rural	Urban	Rural	Urban
Roll	1333	725	761	1156	604	2743
Teachers	21	25	16	34	8	61
Teacher-pupil ratio	1:63	1:29	1:95	1:34	1:75	1:45
Number of teacher participants	2	2	2	2	2	2

The data collection process involved lesson observation, interviews and document review. Two techniques were used to record data. A digital recorder was used to audio tape the voices of teachers and learners and field notes were made to capture what was done in the classroom. Key pedagogic and assessment practices in the lessons were probed in the interviews. The 71 lesson observations and the interviews were transcribed. The classroom observations generated a huge amount of data, more than three hundred pages of transcripts, and all the lessons were accurately transcribed. The long time spent on transcribing the data had the advantage that the content of the lessons got more familiar.

The 71 lesson transcripts and 71 interview transcripts were analysed inductively. The transcripts were read and coded. This led to the identification of categories and patterns in the data (Merriam, 2002: 25). Evidence from the lesson observations, post-lesson interviews and document review was pooled during analysis according to the themes related to continuous assessment which emerged from the data. Conclusions were then drawn on the continuous assessment practices of the teachers in their teaching of Expressive Arts and the challenges they face in implementing the continuous assessment policy in the classroom.

FINDINGS

Teacher preparation

Interview data revealed that the training courses to prepare teachers to implement the continuous assessment policy in the new curriculum were ineffective because the orientation period was too short and topics for orientation were selected by the trainers and not teachers. Furthermore, the orientation programmes were common to all teachers and rarely addressed individual teacher's needs and concerns. As such, teachers found it difficult to comprehend and understand the philosophy, and methods of continuous assessment in the new curriculum. Although follow up in-service teacher professional development activities were carried out to support teachers, the activities did not address the teachers' needs and concerns.

It is important to ensure that all curriculum implementers are aware of the curriculum changes and their objectives and that they are fully prepared for curriculum implementation through intensive and thorough orientation. Ratsatsi (2005) argued that the introduction of a curriculum change may deskil the teachers if not well-prepared. Hence, teachers only implement those aspects of the curriculum that fit well with their set of beliefs. In view of this, it is important to ensure that rigorous and thorough orientation of teachers to a new curriculum's ideals and materials should be taken seriously in any curriculum change implementation process. If not properly oriented to a curriculum innovation like the continuous assessment policy in the new curriculum, teachers can resort to their old ways of assessing the learners as was ascertained by this study.

It, nevertheless, needs to be recognised that even in cases where teachers have been properly oriented to a curriculum change, as curriculum change is a process, it does take time for the teachers to adopt the change.

Teachers' practice of continuous assessment

Base line assessment in the form of oral questions and written classwork as forms of continuous assessment

The study found that teachers were conducting technical forms of continuous assessment. Oral questions and written classwork were the main forms of continuous assessment by the teachers. In general, the teachers frequently called on particular children to answer their questions. If the child was correct they offered congratulations, and if incorrect they called on another child 'to help your friend'. This was a way of checking on the comprehension of individuals and giving feedback with correction in a non-threatening way. When they were correcting written work, they simply marked work right or wrong but had little time to help individuals. Later clarification from a teacher was:

When correcting written work, fast learners receive feedback, a tick, meaning they are correct, they have done well. Slow learners are not missed but given (x) or underline where she/he has missed. This shows that he/she has hasn't understood, and needs individual help, needs extra help at the end of the day. It also helps interested parents to monitor the performance of their child.

In this approach to assessment, learners simply learned to distinguish right and wrong without understanding why a response was right or wrong.

Assessment for rote recall

The study found that assessment activities were based on simple recall of facts that were learned in the lesson and in the previous lessons. The excerpt below, extracted from an Expressive Arts lesson in Standard 7 illustrates some assessment conducted in a lesson, but only of factual recall.

Teacher: Now can you take note books and quickly answer these questions.
(Teacher wrote the following questions on the chalkboard.)

1. What is mirroring?
2. Mention two activities which you can copy from friends?

(The teacher went around the classroom marking the learners. She did the marking for about five minutes.)

Teacher: Most of you failed to answer the questions correctly. What is mirroring?

Learner: Mirroring is an art of copying an action, words or expressions.

Teacher: Thank you very much. Mirroring is an art of copying an action, words or expressions. Our lesson ends here for today. Thank you very much for your attention.

This assessment activity, like the other three observed in the lessons, was different from that of the teacher's guide. The Standard 7 teacher's guide suggested the following assessment tasks for students:

1. What are mirroring activities?
2. Why are mirroring activities significant?
3. Describe some mirroring activities that you do at home and at school.
4. How do mirroring activities differ from other ordinary activities?

While the teacher's task only involved students to recall facts, the same task in the teacher's guide goes beyond simple recalling of facts. For example, the third and fourth questions of the task in the teacher's guide makes connections to students' lived experiences. Yet the teacher's assessment task did not make such connections.

Some teachers often asked the class to reward a learner's answer. Teachers also often gave feedback to learners such as: 'I like that – beautiful – clap hands for her.' This was followed by all children joining in a rhythmic clapping pattern. Unfortunately, the teachers never explained why the answer was 'beautiful'.

Teachers cited continuous assessment as creating additional workload for them as the main constraint. Teachers explained that time constraints inhibited them to teach and at the same time assess the learners. The following were the comments or remarks of some of teachers:

Comments from Teacher 3

Researcher: The teachers' guide says that you are supposed to observe and record each of your learners' performance in every activity of your lesson as part of continuous assessment. Can I have a look at what you have recorded as your learners' performance in the activities of today's lesson?

Teacher 3: [laughs]. I have not recorded the learners' performance. I did not have enough time to teach and assess the learners at the same time. The Ministry of Education also promised to give us registers and materials for assessment but they are not giving us. I just memorise the learners' performance and record later.

Researcher: Can you explain clearly about materials for assessment?

Teacher 3: Rubrics and checklists and registers where to record the learners' performance.

Comments from Teacher 7

Teacher 7: The time is also not enough to teach and record learners' performance at the same time.

Comments from Teacher 9

Teacher 9: I do Continuous Assessment at the end of every 10 lessons. So I will do the next Continuous Assessment at the end of 10 lessons. Resources such as paper are a problem. I do not have these.

Teachers were not recording the learners' performance as required by policy. Teacher 2 assessed language skills instead of Expressive Arts skills. This is evidenced from Teacher 2's remarks:

Researcher: Thanks, did you have any method to assess whether the outcomes of your lesson have been achieved?

Teacher 2: Ya, I think I asked learners some questions.

Researcher: And then you were marking the learners. What did you get from that marking?

Teacher: Sometimes if I say you should write this, I sometimes want to look at something from the learners. Like in that class, sometimes I look at the spellings. Have the learners written correct spellings?

Teacher 2 thus assessed language skills of learners instead of assessing Expressive Arts skills.

The teachers apparently did not understand the policy on continuous assessment which indicates that assessment in the teaching and learning process should be aimed at assessing the achievement of the lesson outcomes the teachers have to fulfil in their lessons.

These findings are consistent with the findings of others on continuous assessment practices of primary school teachers. For example, Adebowale (2008), in his study on continuous assessment policy implementation conducted in the Ondo state of Nigeria, in which he examined the methods adopted by teachers in the implementation of the provisions of a continuous assessment policy, found that there is no agreement amongst the teachers, the implementers of the policy in terms of how regularly continuous assessment should be conducted. The study found that 29% of the respondents claimed that it should be done daily, while 31.6% said it is weekly, 28.1% said it is fortnightly, and 10.5% said it is term based.

How continuous assessment has changed the assessment approaches which the teachers were previously using

When asked how the introduction of continuous assessment has changed the teachers' assessment approaches, teachers' responses were varied. Some of them were of the view that the introduction of

continuous assessment in the new curriculum did not affect their assessment approaches which they have been using before. They indicated that the assessment methods they used to assess the learners previously, such as end of the week, month and the term tests were the same methods they were using to assess the learners even after continuous assessment was introduced. The only difference this time around was that the administration of the weekly and monthly tests were being emphasised. Other teachers however looked at the introduction of continuous assessment as having changed their assessment approaches in such a way that the introduction of continuous assessment has made teachers prepare the suitable assessment methods they would use to assess the learners during the teaching and learning process and this has made them plan and prepare lessons more thoroughly than they previously did before teaching in the classroom. In fact one teacher had this to say:

... a lot of preparation is needed for lessons now because now that continuous assessment is part and parcel of the teaching and learning process, means that a lot has to be done in terms of lesson preparation, preparation of teaching, learning and assessment resources so that learners' performance and achievement is evaluated on a regular basis.

It was also reported that in primary schools where there was more than one teacher for Expressive Arts for Standards 7 or 8, these teachers planned together and shared expertise in areas relating to continuous assessment in which they were not confident to use in the classroom. This has apparently brought team work and better relationships amongst teachers. They were willing to consult each other in areas of difficulty implementing or using continuous assessment, learn from each other, share experiences and expertise in continuous assessment, as the new curriculum has brought new approaches to assessment.

Provision and adequacy of assessment materials

Interviews with teachers indicated that before they were oriented to the new curriculum, assessment materials or resources were distributed throughout the country. These resources included learners' registers and assessment record books for recording learners' performance. However, it was reported that although these assessment resources were distributed to schools, they were not adequate. Assessment resources, just like any other instructional materials are very important to teaching and learning. These findings are consistent with Ratsatsi's argument about the importance of availability of adequate and appropriate resources for successful implementation of an educational innovation.

Ratsatsi (2005) argues that a curriculum change justifies its existence and defines its own delivery strategies embodied in teaching, learning and assessment materials. Therefore, their availability and adequacy are important in a curriculum change implementation. Hence the inadequacy of assessment resources or materials in its first two years of implementation affected the implementation of the continuous assessment policy in the primary schools in Malawi.

Provision of infrastructure and facilities

School principals were asked about the availability of infrastructure and facilities that could facilitate effective implementation of continuous assessment in the new curriculum. Some of them reported that their schools did not have enough classrooms. The classrooms that were available lacked adequate furniture such as desks and chairs. This made some learners sit on the floor which made it difficult for them to write properly. Due to lack of enough classroom space, some schools bunched learners together in one class causing the problem of overcrowding. In one case, about 132 learners were bunched together in one class in Standard 7. The overcrowding in classes made it difficult for teachers to carry out assessment, let alone offer individual help to learners. Such large teacher-learner ratios posed big challenges to teachers' effective implementation of the continuous assessment policy in the new curriculum. This impacted negatively on the achievement of the continuous assessment policy goals and objectives.

These findings are consistent with Khomani's (2005) argument about the importance of provision of necessary infrastructure and facilities to ensure successful implementation of an educational innovation.

Khomani (2005) contended that implementation of an educational innovation is always capital intensive. As such, for a curriculum reform to be successfully implemented, there is need for infrastructure to be available. Thus curriculum reform implementation fails because the inputs in education are not adequate and as a result, inadequate infrastructure militates against the implementation of a curriculum reform. This study rendered support to this.

Lack of infrastructure and facilities is very common in Malawi. This study found that teachers seldom used teaching and learning resources for engaging students in lesson activities on the few occasions they used such resources. When they did employ resources such as a piece of cloth and a needle for practising sewing stitches, the use of the resources was by the teacher only. The learners did not have an opportunity of hands-on learning of practical skills in Expressive Arts. Such a lack of facilities also affected the implementation of the continuous assessment policy as teachers were not able to assess learners' attainment of practical skills. This impacted negatively on the achievement of the continuous assessment policy, goals and objectives.

These findings on inadequate facilities in the twelve classrooms of this study are consistent with what Kaambankadzanja (2001) and Nsapato (2005) have argued – that lack of resources influence teachers' decisions in the classrooms. The lack of resources also validates the contention of some observers – that the Ministry of Education lacks commitment in the implementation of school curricula. Revelations at the Malawi National Educational Conference in 2005 (Mhango 2008) showed that the Ministry drags its feet in dealing with pertinent issues that affect the quality of education in the country. Kaambankadzanja (2001), argued that the Ministry's sluggish commitment to the planned educational activities reduced the effective implementation of the Malawi Primary Curriculum and Assessment Reform (PCAR). Nsapato (2005) also argued that the Ministry fails to achieve most of its plans because of a lack of aggression in tackling problems affecting the quality of education in the country.

Supervision

Some of the school principals reported that they supervise their teachers in their implementation of continuous assessment. For example, one of the school principals remarked that

I organised an in-service training for the teachers here at the school on Assessment and I taught them how to use portfolios and other assessment tools. We also have a special mission statement on Continuous Assessment at this school.

When the school principal was requested if he could share the schools' mission statement on continuous assessment, he shared the mission statement which had the following as the intentions of the mission statement:

... to encourage teachers gather valid and reliable information about learners' performance; to improve the teaching and learning process through reliable feedback and to ensure that 98% of teachers assess learners through Continuous Assessment (CA) in addition to Summative Assessment (SA).

However, when the teachers were asked about whether they are supervised in their implementation of continuous assessment, the teachers reported that school principals and section heads hardly observed lessons and their assessment practices in their classrooms. The reasons given by the teachers for this were many and varied. Many teachers reported that because of understaffing, section heads and in some

cases school principals had classes of their own to teach. Due to too much workload, they did not have time to observe lessons. Thus, the PCAR was based on the wrong assumption that school principals would supervise teachers which this study has establish not be the case.

Continuing Professional Development for teachers

The Standards 7 and 8 teachers who participated in the study were asked about the support they got as regards professional development to help them in implementing continuous assessment effectively. From the interviews, it was reported that most of the in-service training that were organised for them focused on teaching in general, and not continuous assessment specifically. For example, one of the teachers remarked:

I was trained in teaching Expressive Arts. I was not trained on how to use Continuous Assessment.

In fact, some teachers complained about the lack of continuing professional development with the implementation of the continuous assessment policy. The teachers felt the need for continuing professional development activities because they reported that it was difficult for them to do or conduct continuous assessment due to lack of sufficient background knowledge of continuous assessment. This shows that there was a need for rigorous continuous professional development of teachers if the teachers were to implement continuous assessment effectively. These findings are consistent with Khomani's argument that implementation of an educational innovation is built around a climate of acceptance for change.

Khomani (2005) argued that an educational change should be facilitated by ensuring that the change meets recognised needs, establishes clear goals, develops support systems and provides in-service training and needed resources for institutional growth. However, the implementation process often overlooks implementers' skills and beliefs that can affect the implementation. Since the focus of the in-service training conducted by the national curriculum development centre, the Malawi Institute of Education on continuous assessment was school-based in-service training of teachers, the primary education teaching methods advisors (PEAs) who are overseers of a number of schools were left-out. This meant that the PEAs who were key in the implementation had not yet conceptualised the change and were not clear about how they could assist the teachers in implementing the continuous assessment policy effectively. Thus they could not perform their roles and responsibilities in relation to the implementation of the continuous assessment policy. Hence, they lacked the skills required to perform their roles as supervisors in the teachers' implementation of continuous assessment.

These findings are consistent with Chimombo's (2001) argument that effective implementation of social interventions require time, personal interactions and contacts and other forms of people-based support, and there is no substitution for the primacy of personal contact among implementers, and between implementers and planners if the difficult process of unlearning old roles and learning new ones is to occur. There was little contact between schools and the primary education advisors. This type of implementation often threatens and deskills the teachers who may resist implementing the proposed change because they feel abandoned and isolated. This points to the fact that curriculum reform implementation in Malawi is based on the wrong assumption that the bureaucratic structures in the education system would facilitate implementation. On the contrary, most of these structures are marred by weak administrative capacity. As a result curriculum innovations end up being ineffectively implemented.

Challenges in the implementation of continuous assessment

Teachers of Standards 7 and 8 were asked to state the challenges they faced in the implementation of continuous assessment. Some of these problems were reported as follows: inadequate and lack of assessment materials such as record books; the absence of continuous professional development of teachers

was another challenge teachers were facing in the implementation of continuous assessment: the large teacher-learner ratio was posing a big challenge in assessment during instruction and the preparation of assessment tools and assessing learners continuously needed a lot of time. Assessing learners continuously proved to be difficult due to lack of assessment resources and space for storing the portfolios and rubrics. Furthermore, teachers lacked expertise in continuous assessment and found it difficult to cope with the task. The challenges that have been highlighted above indicate that curriculum reform implementation is a multi-dimensional process that requires meeting the required needs of teachers and developing support systems for implementation, providing training and resources for the implementation to be effective. These findings are consistent with Middleton and Verspoor's (1990) arguments about the need for new management strategies for successful implementation of an educational innovation. Middleton and Verspoor argued that innovations seeking to promote change usually require different management strategies. Planners must not only be concerned with the innovation but also with the complex process of introducing and institutionalising change. However, curriculum reforms implementation in Malawi are based on the assumption that since it is centrally developed by the Ministry of Education, whatever changes the curriculum brings would be effectively implemented without taking into account the needs of the implementers as well as the contexts in which the change will take place.

DISCUSSION

The conceptual distinctions of Illuminative evaluation, the 'instructional system' and 'learning milieu', were employed in this study to compare the PCAR with what teachers actually do in conducting continuous assessment.

This study found a 'gap' between the 'instructional system' and the learning milieu. The study found that in the majority of lessons, learners were not assigned any specific tasks to monitor their learning progress in the lessons. Continuous assessment was evident only in 5% of the lessons (four out of 71 lessons of Expressive Arts observed in the study). In addition to the irregular integration of assessment in the teaching and learning process in the lessons, the classroom observations also showed that there was no teacher who administered the end of month tests for purposes of summative assessment, and in cases of written assessment tasks, the tasks were merely aimed at recall of facts. Teachers gave two reasons for their failure to integrate continuous assessment in their lessons. Firstly, they said that integrating assessment in the lessons created additional workload for them. The teachers indicated that combining teaching and assessment required a lot of time and they did not have time to do that within the official allocated time of 35 minutes duration of an Expressive Arts lesson. Secondly, the teachers said that they were not trained on how to do continuous assessment.

The teachers' varied perceptions about continuous assessment observed in the study shows that the process of educational innovation was planned at the centre and fed into the system for implementation. These findings are consistent with Khomani's argument about the challenges of top-down educational reforms.

Khomani (2005) argued that top-down educational reforms are based on the assumption that the process of educational reform is a rational sequence of phases in which an educational innovation is discovered, developed, produced and disseminated to the users to implement. Though stakeholder consultations might have been there in the PCAR process, its implementation strategy might have been ineffective.

These findings are also consistent with Middleton and Verspoor's (1990) argument about the need for educational innovations to involve those to implement them if they are to be successful. Thus Middleton and Verspoor (1990) argued that educational innovations are 'people-centred' activities. They depend for their success on the values, attitudes and behaviour of intended beneficiaries and on their effective participation in the educational innovation's design and management. Hence, the teachers' varied perceptions on continuous assessment might have been influenced by their lack of involvement and participation in

the design and development process of the continuous assessment policy. Furthermore, implementing continuous assessment may have needed an extensive amount of professional development of teachers especially in training them on how continuous assessment differs from continuous testing. However, this was not the case with the Expressive Arts teachers. The kind of training teachers went through did not prepare them enough to implement continuous assessment. This was the reason why teachers were finding it difficult to integrate assessment in the teaching and learning process, thereby making its implementation ineffective.

The findings of this study further confirm what the Commonwealth of Learning (2000) has argued that centre-periphery approach to educational innovation's design and development is often ineffective because it does not bring on board teachers who are the implementers of the proposed innovations during the innovation's development process. Therefore, teachers are less obliged to implement the suggested innovations or changes. This was exactly what was happening in the twelve classrooms that were observed in this study.

CONTRIBUTION TO KNOWLEDGE OF THE STUDY

The study has established that continuous assessment has inherent challenges of implementation in the country. The contexts of South Africa where continuous assessment may have been conceived are different from those of Malawi. Continuous assessment needs small class sizes as well as adequate resourcing for it to work. As a third world country, Malawi does not have adequate resources for implementing a curriculum innovation whose design is a product of some contextual realities which are different from those where the curriculum design was conceived. This study has confirmed the challenge of implementing continuous assessment in the new curriculum.

The study informs the decision makers; the Malawi Institute of Education, the national curriculum development centre in Malawi and the Ministry of Education on the appropriate strategies to adopt in the implementation of the continuous assessment policy in the country. Other partners in the process of implementation, particularly the teachers who took part in the research may also find the information useful. The study may also be of interest to a wider research community in Malawi as well as in the other countries in the South African Development Community (SADC) region. This study has opened up more areas for further research work that can be carried out or conducted in Malawi and in other countries in the SADC region.

CONCLUSION

This study has established that teachers' practices were characterised by an informal, technical form of assessment, which privileged rote recall of facts. This shows that teachers have a restricted understanding of continuous assessment policy in the new curriculum in Malawi.

These findings are consistent with the findings of Susuwele-Banda (2005: 115) in his study of assessment practices of teachers in rural primary schools in Malawi. Susuwele-Banda noted that work done in class was not used as feedback for pupils. The teachers lacked both knowledge and skills to implement feedback effectively. They gave no individual written or verbal feedback to students. There was no written feedback in students' notebooks apart from crossed out work or work marked correct and in some cases marks indicating how many questions the student got correct.

This study thus recommends that teachers be developed in continuous assessment principles and practice both at pre-service and in-service levels including:

- a. how answers to oral questioning in lessons informs teachers' actions in the classrooms can be more carefully spread around the class
- b. how peer and self assessment could be productively used to assist with assessment.

REFERENCES

- Adebowale, O.F. (2008) *Continuous assessment policy implementation in selected local government areas of Ondo state (Nigeria): Implications for successful implementation of the UBE program* (online) <http://cng.kedi.re.kr> (Accessed 15 July, 2009).
- Chimombo, J.P.G. (2001) 'Educational Innovations in Developing Countries: Implications and Challenges for Policy Change in Malawi' *Journal of International Cooperation in Education* 4(2) pp 39-54.
- Commonwealth of Learning (2000) *Curriculum design and development*. Domasi: Domasi College of Education.
- Croft, A. (2002) 'Singing under a tree: Does oral culture help lower primary teachers be learner-centred?' *International Journal of Educational Development* 22 pp.321-337. www.elsevier.com/locate/ijedudev (Accessed 1 March, 2010).
- Der Berg, S.V. and Shepherd, D. (2008) *Signalling performance: Continuous assessment and matriculation examination marks in South African schools*. Matieland: University of Stellenbosch.
- Du Plessis, P., Conley, L. and Du Plessis, E. (2007). *Teaching and learning in South African schools*. Pretoria: Van Schaik Publishers.
- Gipps, C.V. (1994) *Beyond Testing: Towards a Theory of Educational Assessment*. The Falmer Press: London.
- Kaambankadzanja, D.O.P. (2001) *The changing role of primary school head teacher in Malawi*. Unpublished Masters, University of Manchester, Manchester.
- Khomani, J.P. (2005) 'Primary Curriculum and Assessment Reform: Background, process and challenges' Paper presented at the Regional Curriculum Conference, Mangochi: Malawi.
- Le Grange, L. and Reddy, N. (2002) 'Postgraduate research supervision in a socially distributed knowledge system: some thoughts' In J. Dryer (Ed.) (2008) *The educator as assessor*. Van Schaik Publishers: Pretoria.
- McMillan, J.H. (1997) *Classroom assessment: principles and practices for effective instruction*. Allyn and Bacon: Boston.
- Merriam, S. (2002) *Qualitative Research and Case study applications in Education*. San Francisco: Jossey-Bass.
- Mhango, N.A.C. (2008). *An exploration of the teaching of Social Studies in primary school: How does a social studies teacher apply the teaching/learning methods in training colleges in a classroom situation?* Unpublished Masters research project, Virginia Polytechnic Institute and State University, Blacksburg, USA.
- Middleton, R.D.J. and Verspoor, A. (1990) *Planning Educational Reform in Developing Countries: The Contingency Theory*. London: Duke Press Policy Studies.
- Malawi Ministry of Education. (2009) *Primary Curriculum and Assessment Reform Framework*. Zomba: Government Press.

Nsapato, L. (2005) 'Factors affecting the quality of basic education in Malawi' Paper presented at the Malawi National Education Conference, Lilongwe, Malawi.

Parlett, M. and Hamilton, D. (1976) *Evaluation as Illumination: A New Approach to the Study of Innovation Programmes*. Edinburgh: SCRS.

Ratsatsi, D. (2005) 'Challenges in Curriculum Innovations: Lessons from Botswana's Experiences' Paper presented at the Regional Curriculum Conference, Mangochi: Mala.

Salvia, J. and Yeseldyke, J.E. (1995) *Assessment*. Boston: Houghton Mifflin Company.

Susuwele-Banda. (2005) *Classroom Assessment in Malawi: Teachers' perceptions and practices in Mathematics*. Unpublished Doctor of Philosophy Thesis, Virginia Polytechnic Institute and State University, Virginia.

Ward, C. (1980) *Designing a scheme of assessment*. Cheltenham: Stanley Thorns Publishers.

Withers, J.R. (1994) *Conceptual dictionary*. Kenwyn: Juta.

List of reviewers

- Dr N. Agherdien, The Independent Institute of Education, South Africa
- Dr D.S. Allison, Applied Science University, Kingdom of Bahrain
- Professor B. Anderson, The Da Vinci Institute, South Africa
- Dr P. Austin, Nelson Mandela Metropolitan University, South Africa
- Professor C. Boughey, Rhodes University, South Africa
- Ms G. Castrillon, Milpark Business School, South Africa
- Dr S. Costandi, Ahlia University, Kingdom of Bahrain
- Professor A. Delport, Nelson Mandela Metropolitan University, South Africa
- Dr J.J. Dhlamini, University of South Africa, South Africa
- Dr D. D'Souza, RMIT University, Australia
- Dr F. du Plooy-Cilliers, The Independent Institute of Education, South Africa
- Dr D. Edley, Nelson Mandela Metropolitan University, South Africa
- Professor G. Ferreira, University of South Africa, South Africa
- Ms N. Gxowa, University of Leeds, United Kingdom
- Professor J. Harland, RMIT University, Australia
- Dr J. Lück, Nelson Mandela Metropolitan University, South Africa
- Professor M. Maharaj, University of Kwa-Zulu Natal, South Africa

- Mr N.J. Manson, Monash South Africa, South Africa
- Professor G. Moyo, University of Fort Hare, South Africa
- Professor T. Mwamwenda, Nelson Mandela Metropolitan University, South Africa
- Mr J. Naidoo, Durban University of Technology, South Africa
- Dr K.M. Ngcoza, Rhodes University, South Africa
- Ms N. Payne, The Independent Institute of Education, South Africa
- Ms M. Pritchard, University of Johannesburg, South Africa
- Dr A. Roux, North West University, South Africa
- Professor S. Schoeman, University of South Africa, South Africa
- Mr D. Steenberg, Nelson Mandela Metropolitan University, South Africa
- Dr M.D. Tshelane, University of the Free State, South Africa
- Ms B. Wilson-Thomson, University of the Witwatersrand, South Africa
- Mr P. van der Wiele, Bahrain Polytechnic, Kingdom of Bahrain
- Mr A. Wentzel, University of Johannesburg, South Africa

Erratum: Apologies for the misprint of the name of Dr J.J. Dhlamini of the University of South Africa in the List of reviewers in Volume 9 2014 of this journal.

Notes for contributors

Manuscripts should be sent to the Editor. They should be typed in one and a half spacing Arial font size 12, in A4 format, in MS Word and should not exceed 5000 words in length, excluding tables, figures and references. Manuscripts may be submitted by e-mail. The overall style for abstract, title, headings, figures and references should be in accordance with that of the American Psychological Association (APA 2004, 5th ed. Style Manual). Tables and Figures should be numbered by Arabic numerals. Each manuscript should be accompanied by a title page and an Abstract of 150-200 words on a separate sheet. Manuscripts not conforming to these requirements will not be considered for publication.

The full postal and e-mail address of the author should be included on the title page. Proofs will be sent to authors if there is sufficient time to do so. They should be corrected and returned within 48 hours of receipt. The editor reserves the right to publish without proofs having been signed-off by the author.