2021 STEMI Community of Practice Conference PROCEEDINGS

S.T.E.M.I

Olympiads and Competitions

Community of Practice

Conference

science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

ASTEMI
SCIENCE TECHNOLOGY ENGINEERING MATHEMATICS INNOVATION
OLYMPIADS & COMPETITIONS

NRF National Research Foundation

SAASTA South African Agency for Science and Technology Advancement

STEMI COMMUNITY OF PRACTICE CONFERENCE

BACKGROUND

The Department of Science and Innovation (DSI) through the Science Engagement Strategy seeks to develop a society that is literate and knowledgeable about science, and critically engages with science. The strategy further aims to promote science communication to enhance science engagement in South Africa. It also encourages school-going youth to participate in science and contribute to efforts to achieve the National Development Plan (NDP) (Vision 2030) target of increasing the number of students eligible to study towards mathematics and science-based degrees to 450 000 by 2030.

Central to the implementation of the Science Engagement Strategy is the use of science, technology, engineering, mathematics and innovation (STEMI) Olympiads and related competitions as instruments to identify learners with potential to follow SET careers.

The STEMI Olympiads and related competitions programme targets learners from grade one to twelve especially those in remote disadvantaged areas, including urban areas (townships) with the objective of increasing the footprint (covering municipal districts with limited prior coverage) of participation. Learners participate in a range of Olympiads and related competitions in mathematics, science, coding and robotics as well as those that focus on innovation. The success and sustainability of the programme hinges on mentoring and coaches for learners, and this is done in the form of volunteerism. The success of the programme is measured by its ability to be inclusive, accessible, sustainability and expansion, amongst other things.

The Community of Practice conference create a good and conducive platform for different stakeholders and communities engaged in STEMI, to come together and share their knowledge, skills and expertise in this field.

CONFERENCE SCOPE

The STEMI Olympiads and Competitions Community of Practice Conference is a biennial conference that is dedicated to the advancement of the Science, Technology, Engineering, Mathematics, and Innovation (STEMI) Olympiads and Competitions in South Africa by creating a community of practice where best practices are identified and benchmarked. This is achieved by bringing Olympiad and related competition organisers, STEM professionals and academics, industry, STEMI organisations and institutions representatives together to present academic and non-academic research papers, to do demonstrations and talks, and to facilitate a platform for engagement between parties.

OBJECTIVES OF THE CONFERENCE:

- To positively contribute towards a STEMI-driven culture.
- To create a platform for collaborative problem solving.
- To act as a catalyst between people and organisations.
- To facilitate the development of tools to improve the inflow of science in society.
- To assist in transforming innovative ideas and actions into benchmarked practices.

EDITORIAL INTRODUCTION AND OBSERVATIONS:

Dr John Butler-Adam, Conference Editor

2021 STEMI CoP CONFERENCE

Full many a flow'r is born to blush unseen,
And waste its sweetness on the desert air.
…
Here rests his head upon the lap of Earth
A youth to Fortune and to Fame unknown.
Thomas Gray: 1751

It might seem strange to begin observations about the 2021 STEMI CoP Conference with a few lines from a poem written in England 270 years ago. Yet they capture precisely much of what Department of Science and Innovation (DSI) SAASTA, and STEMI CoP Conferences are about.

At one end of the scale of scientific and related achievements, South Africa holds its own amongst much larger and wealthier countries across the world. *The Academy of Science of South Africa*, for example, lists over 50 of its own members, women and men, who hold an array of prestigious awards, and who are leaders in, and major contributors to, a wide range of sciences that have had an impact across global science. Substantially more scientists from outside the Academy could readily be added to the list.

At the other end of the scale, in 2020, 63% of young people in the 16 – 35 age cohort (*Trading Economics*: South Africa Youth Unemployment Rate2021 Data | 2022 Forecast https://tradingeconomics.com/south-africa/youth-unemployment-rate" https://tradingeconomics.com/south-africa/youth-unemployment-rate) were NEETs (Not Employed, in Education, or Training) – in other words, unemployed and in social and economic danger. Slightly more girls are part of this group than boys. By implication, as few as 37% of that age group may be in one form of education or other, while some may have employment using varying levels of skills. Of course, not everyone would necessarily wish to work directly in STEMI fields. Others might well choose to be bankers, farmers, fashion designers, members of the police force or sales specialists. But almost no career at all is now feasible without at least an operational, basic knowledge of the natural sciences, especially Mathematics.

And herein lies the tragedy of Gray's lines: "full many a flow'r is born to blush unseen/ And waste its sweetness on the desert air …/ A youth to fortune and to fame unknown.

This is a heart-breaking indication of the challenges against which the STEMI CoP and its staff labour each day in the interests of young people and the nation, reflected in the theme and sub-themes of the 2021 Conference.

The primary theme was "STRENGTHENING THE IMPACT OF OLYMPIADS AND COMPETITIONS THROUGH COLLABORATIONS, PARTNERSHIPS AND COOPERATIVE OPPORTUNITIES" with three sub-themes:

1. contemplated impact of STEMI Olympiads and competitions;
2. the reach objective of STEMI Olympiads and competitions;
3. collaborations, partnerships and cooperative opportunities necessary for successful STEMI Olympiads and competitions.

What follows is rather different, coming from an editor of long-standing but whose work with conference organising committee is rather less than eight months. During that time, I have come to learn just how extensive, complex and demanding the work is in this essential field, and how much support it demands from so very many people with so wide a range and variety of skills. By this I mean not just those whose direct and arduous work this is, but also those whose related and committed skills are needed and are willingly shared to ensure the academic success of the Conference.

Part of this work includes a rigorous review process almost identical to the processes followed by journals of high international standing.

The papers published here in the Proceedings of the 2021 Conference reflect not just a commitment to academic integrity, but also to high standards and ongoing concerns faced by conferences (especially in this case) whose publications are not currently recognised by the Department of Higher Education and Training (DHET) for subsidy purposes[1]. The papers submitted for consideration for the various categories of the Conference have shown a wide landscape of interest in promoting and supporting education in STEMI (inclusive of the Arts). They have also shown, it must be recognised, an equally wide range of quality and relevance. This means that STEMI CoP conference experience, careful review and a focus on the Conference Themes are an essential part of the work that leads up to the three "core days" of the Conference, and what follows.

In this regard, two further issues deserve particular attention. First, of the papers submitted, relatively few fall into the Conference "Academic" category. Some of those do not succeed in meeting the requirements of the review process. And of those that do succeed, some are withdrawn (notably because of the benefits of the STEMI review process). This challenge needs to be addressed along some of the papers that classify as "Demonstrations" are difficult to accommodate through online conferencing.

It follows, perhaps, that my closing editorial and scholarly concerns fall into two broad categories. First, among the work submitted by academics, I have missed a sufficiency of papers that are authored by young scholars and practitioners in the field. After all, these will be the core players in the next stage of the STEMI and relevant arts) work. In the second category, are the submissions by highly regarded and experienced practitioners working in partnership with younger researchers in the relevant range of STEMI fields and practice – but again, while such combinations are important, it has not always been easy to identify that the authorship draws on both the seriously experienced *and* the new practitioners who have been working together.

Why these are concerns, however major or minor they may be, is because of the clear need for more and more "younger" and "older" researchers (not a matter of age but experience and engagement), which is at the core of STEMI work. These are fields that must grow from the base, and – experience support which must keep growing. This must be addressed for future conferences that they will, rests on support for STEMI (and vice versa). This is critical work for South Africa, its people and its fundamental national strengths.

[1] The DHET has insufficient funds for subsiding academic/scientific publications of any kind, and the suspension of subsidies for Conference Proceedings reflects this situation. The most recent DHET Gazette: https://www.dhet.gov.za/Policy%20and%20Development%20Support/Research%20Outputs%20policy%20gazette%202015.pdf states that conference proceedings from approved conferences may be subsidized, but the list of approved conferences is no longer published or available.
See also https://www.ufs.ac.za/docs/librariesprovider41/research-resources-documents/dhet-ro-communique-2-of-2015.pdf?svrsn=9380d221_0

2021 STEMI Community of Practice Programme

Day 1: Tuesday, 20 July 2021

Programme Director: **Mr Steve Sherman** Session Scribe: **Dr John Butler-Adam**					
09:00 – 09:05	Welcome				
09:05 – 09:20	Overview of STEMI Community of Practice: **Mr Moloko Matlala**				
09:20 – 09:25	Introduction of Deputy Minister: **Dr Jabulani Nukeri**				
09:25 – 09:45	Conference opening: **Mr Buti Manamela (Deputy Minister: Higher Education, Science & Innovation)**				
09:45 – 10:05	Message from NRF Group Executive: **Dr Beverley Damonse**				
10:05 – 10:10	Introduction of Keynote Speaker: **Mr Steve Sherman**				
10:10 – 10:30	Keynote Address: **Dr Kristof Fenyvesi** Researcher of STEAM (Science, Technology, Engineering, Arts and Maths) and founder of Global STEAM network, Finnish Institute of Educational Research, University of Jyväskylä, Finland				
10:30 – 10:50	Questions & Discussion				
10:50 – 11:00	Break				
11:00 – 12:15	***Transformation and inclusivity in STEMI Olympiads and related competitions*** **Mr Isaac Ramovha**				
12:15 – 12:45	Break				
Programme Director: **Dr Gillian Arendse**					
12:45 – 12:50	Welcome and Session Brief				
Room 1 Session Chair: **Dr A Binneman** Session Scribe: **Ms Makhanana Nkhwashu** ***Note**: Papers are delivered consecutively*				**Room 2** Session chair: **Mr Elijah Nkosi**	**Room 3** Session chair: **Mr J de Vries**
12:50 – 13:55	Paper 1 (Non-Academic) (15min)	Paper 2 (Non-Academic) (15min)	Paper 3 (Non-Academic) (15min)	Demonstration (50 min)	Demonstration (50 min)

	Collaboration is more than working together towards the same goals. Mr A Schlemmer (Eskom Expo) Mr F Mashate (Scifest)	**Beyond the Rhetoric: Rethinking Reach and Access of Olympiads and Competitions for Rural Learners** Ms K Naidoo (Eskom Expo) Mrs N Dookie (Eskom Expo) Mrs D Mlambo (Christoph Meyer Maths and Science Centre)	**Extending the reach of STEMI Olympiads and Competitions through systemic interventions: Reflecting on the collaboration between the North West Provincial Department of Education and Eskom Expo for Young Scientists** Ms Moloedi (Eskom Expo) Ms Mekgwe (NW DoE)	**GeoGebra Classroom for post-COVID Mathematics learner support over distance** Prof W Olivier (Nelson Mandela University)	**Rural robotics clubs are possible** Mr F Spies (Split Second Science)
	Discussion (15 minutes)			Discussion (10 minutes)	Discussion (10 minutes)
13:55 – 14:55	**Room 1** Session Chair: **Mrs S Veldsman** Session Scribe: **Ms Nalini Dookie** ***Note***: *Papers are delivered consecutively*			**Room 2** Session Chair: **Mr A Mashakeni**	**Room 3** Session Chair: **Ms K Selepe**
	Paper 1 (Academic) (20 min) **An exploratory analysis of the potential for the use of MOOCs in support of STEM engagement** Dr P Gouws (UNISA) Prof H Lotriet (UNISA) Dr M Katumba (UNISA)		Paper 2 (Non-Academic) (15min) **How mathematical challenges can improve non-routine problem solving in learners from lower quintile schools.** Ms M Trichardt (MG Analytics)	Workshop (50 min) **Topic: Coding Unplugged** Facilitator: Prof J Greyling (University of Nelson Mandela) Mr S Mokoena (Good Work Foundation)	Workshop (50 min) **Topic: Cyber Safety for Educators** Facilitator: Prof E Kritzinger (UNISA)
	Discussion on presentations (25 min)			Discussion (10 minutes)	Discussion (10 minutes)
14:55 – 15:45	**Plenary discussion – Q&A:** **Scribe: Ms Makhanana Nkhwashu**				
15:45 – 15:55	Networking Briefing and Ice Breaker: **Mr Steve Sherman**				
15:55 – 16:15	**Room 1** Networking Facilitator:	**Room 2**	**Room 3** Networking Facilitator:	**Room 4** Networking Facilitator:	

	Ms Catherina Steyn	Networking Facilitator: **Mr Steve Sherman**	**Mr N Swartz**	**Mr Danie Heymans**

Day 2: Wednesday, 21 July 2021

<table>
<tr><td colspan="6">Programme Director: Dr Gillian Arendse</td></tr>
<tr><td>09:00 – 09:10</td><td colspan="5">Welcome and Session Brief</td></tr>
<tr><td></td><td colspan="3">Room 1
Session Chair: Dr Anton Binneman
Session Scribe: Mr Gerald Maluleke

Note: Papers are delivered consecutively</td><td>Room 2
Session Chair:
Mr Akash Dusrath</td><td>Room 3
Session Chair:
Ms Ellie Olivier</td></tr>
<tr><td rowspan="2">09:10 – 10:10</td><td colspan="2">Paper 1 (Academic)
(20 min)

The response of low quintile South African learners to a problem-based programme for developing skills relevant to the Expo for Young Scientists competition
Dr A Stott (University of Free State)</td><td>Paper 2 (Academic)
(20 min)

A comparative analysis of approaches to the assessment of problem-solving activities
Dr C Long (University of Johannesburg)
Dr A van der Nest (UNISA)</td><td>Demonstration
(50 min)

Workshop on the process, and value, of geocoding schools participating initiatives or programmes
Ms M Trichardt (MG Analytics)</td><td>Demonstration
(50 min)

When Mathematics meets Art
Ms C Steyn (NMU)
Prof W Olivier (NMU)</td></tr>
<tr><td colspan="3">Discussions (20 minutes)</td><td>Discussions (10 minutes)</td><td>Discussions (10 minutes)</td></tr>
<tr><td rowspan="2">10:15 – 11:15</td><td colspan="3">Room 1
Session Chair: Dr A Bissessur
Session Scribe: Mr David Ramaboka
Note: Papers are delivered consecutively</td><td>Room 2
Session Chair:
Mr S Manxoyi</td><td>Room 3
Session Chair:
Mr N Swartz</td></tr>
<tr><td>Paper 1(Non-Academic)
(15min)</td><td>Paper 2(Non-Academic)
(15min)

Using environmental education to prepare</td><td>Paper 3(Non-Academic)
(15min)

Exploring Gender and Robotics - A case study of the I-SET</td><td>Demonstration
(50 min)

A framework for designing and</td><td>Demonstration
(50 min)

Toys from Trash - using online</td></tr>
</table>

	Do STEMI Olympiads and competitions enhance inquiry learning in the curriculum and prepare learners with C21 skills? Mr D Haripersad (Western Cape Education Department) Mr L Manas (Eskom Expo)	**learners for STEMI Olympiads and competitions in a transformational manner** Mr A Schlemmer (Eskom Expo) Ms CL Cloete (Wildlife & Environment Society of SA -WESSA)	**Robotics, a community engagement project** Dr T Dirsuweit (UNISA) Dr P Gouws (UNISA)	**communicating experimental investigations for the Expo for Young Scientists competition** Dr A Stott (Angela Stott Learning & Teaching Aids)	**platforms to prepare learners for competitions** Dr T Reinhardt (UKZN – Science and Technology Education Centre) Mr C McCartney (Eskom Expo)
	Discussions (15 minutes)			Discussions (10 minutes)	Discussions (10 minutes)
11:15 – 12:00	Plenary Discussion – Q&A **Scribe: Mr Gerald Maluleke**				
12:00 – 12:30	**Break**				
Programme Director: **Mr Steve Sherman** Session Scribe: **Ms Mkhanana Nkhwashu**					
Panel Discussion: **Inclusivity in the digital era: How to bridge the digital divide**					
12:30 – 12:35	**Dr Derek Fish** (Director, UniZulu Science Centre) **Dr David Johnson** (Adjunct Senior Lecturer, ICT4D, Computer Science Department, University of Cape Town) **Mr Daniel Johnson** (Masters student in Astrophysics, UCT)				
12:35 – 13:05	Panel Presentations				
13:05 – 13:30	Discussion & Questions				
13:30 – 13:45	**Break**				
Programme Director: **Mr Livhuwani Masevhe**					
13:45 – 13:50	Welcome and Session Brief				
13:50 – 14:50	**Room 1** Session chair: **Dr Maria Kekana** Session Scribe: **Ms Lithakazi Masilela**			**Room 2** Session Chair: **Mr Lyndon Manas**	**Room 3** Session Chair: **Mr N Swartz**

	***Note**: Papers are delivered consecutively*				
	Paper 1(Non-Academic) (15min) **Preparing learners for STEMI competitions: A case study of a collaborative online approach** Dr T Reinhardt Ms N Dookie	Paper 2(Non-Academic) (15min) **The Role of Print and Digital media in transforming Olympiads and competitions: A report on the significance of the reach by Eskom Expo for Young Scientists' activities** Mr I Marume (Eskom Expo) Mr JeVanne Gibbs (Eskom Expo)	Paper 3(Non-Academic) (15min) **Developing a language of Science through cooperative learning in a rural grade 11 Life Science classroom** Mr A Obilana (PRAKIS Educational Services)	Educator Workshop GET (50 min) **Digital tools to level up your STEM teaching (online and off-line)** Mr S Sherman	Educator Workshop FET (50 min) **Beyond Facts – Finding Fun in Physics** *Dynamic tools to spice up your Physics lessons, whether live or virtual:- a problem solving approach with: simulations, experiments and applications.* Dr D Fish
	Discussions (15 minutes)			Discussions (10 minutes)	Discussions (10 minutes)
14:50 – 15:15	Plenary Discussion – Q&A Scribe: **Ms Lithakazi Masilela**				
15:15 – 15: 30	***STEMI Support and Development Framework: Final inputs and adoption*** Mr B Lesch Session Scribe: **Mr Herman Bosman**				
15:30 – 15:35	Closure & Briefing for the 22 July				

Day 3: Thursday, 22 July 2021

Programme Director: **Mr Parthy Chetty**
Session Scribe: **Ms Makhanana Nkhwashu**

10:00 – 11:00	**Room 1** Facilitator: **Mr Tsepo Majake** Scribe: **Mr Patrick Rasehwete** Topic: Contemplated **impact** of STEMI Olympiads and competitions	**Room 2** Facilitator: **Ms Thandeka Mhlanga** Scribe: **Mr Chris McCartney** Topic: The **reach** objective of STEMI Olympiads and competitions	**Room 3** Facilitator: **Mr Lyndon Manas** Scribe: **Mr A Mashakeni** Topic: **Collaborations**, **partnerships** and **cooperative opportunities** necessary for successful STEMI Olympiads and competitions
11:00 – 12:30	Report-back Session		
11:00 – 11:15 11:15 – 11:30	Report back on Theme 1: Contemplated impact of STEMI Olympiads and competitions – **Mr Tsepo Majake** *Discussion, Questions & Recommendations*		
11:30 – 11:45 11:45 - 12:00	Report back on Theme 2: The reach objective of STEMI Olympiads and competitions - **Ms Thandeka Mhlanga** *Discussion, Questions & Recommendations*		
12:00 – 12:15 12:15 – 12:30	Report back on Theme 3: Collaborations, partnerships and cooperative opportunities necessary for successful STEMI Olympiads and competitions - **Mr Lyndon Manas** *Discussion, Questions & Recommendations*		
12:30 – 13:00	**Break**		
13:05 – 13:10	Welcome & Guest Speaker Introduction		
13:10 – 13:30	**Dr Mmaki Jantjies** - Head of Innovation Telkom (previously from University of Western Cape) Topic: **The role of youth in technology, reshaping our digital future** Profile: Mmaki Jantjies holds a PhD in Computer Sciences and is one of Africa's foremost thought leaders in technology for development particularly in education technology. Having led two academic departments, she has published research on local and international academic journals and conferences as well as on several public platforms such as Popular Mechanics, Fast Company and CNBC.		
13:30 – 13:45	Questions and Discussion		
13:45 – 14:30	Recommendations & Conference Resolutions: **Mr Moloko Matlala**		
14:30 – 14:35	Announcement of the 2023 Theme: **Mrs Erna Taljaard**		
14:35 – 14:45	Vote of Thanks and Closure: **Ms Krishnie Naidoo**		

Articles Presented

Towards an understanding of the scope and focus of existing research that could inform the use of MOOCs in STEM Engaged Scholarship

Dr PM Gouws (gouwspm@unisa.ac.za)
Prof H Lotriet (lotrihh@unisa.ac.za)
Dr MG Katumba (KanakanaMG@tut.ac.za)

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October 2020
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Abstract: The focus of this paper is a systematic exploratory review of the literature to explore the scope and extent of existing Science, Technology, Engineering and Mathematics (STEM) Massive Open Online Course (MOOC) literature related to engaged scholarship. This topic has become important, as MOOCs are becoming an increasingly significant vehicle for STEM engagement in the context of engaged scholarship. This is due to inter alia decreased university budgets for community projects and the impact of the pandemic on rules of engagement with communities. The aim of the authors in further phases of the project is to incorporate good practices from literature into the design of science engagement MOOCs at the University of South Africa (Unisa). This paper explores the existing body of STEM MOOC papers in terms of author demographics, subject focus, learner level and the aspect of the MOOC research focus (such as design, content, assessment). The research reported on in this paper used 204 scholarly publications, where both STEM (or a STEM subject) and MOOC are the focus of the paper. The findings of the systematic review show that most of the research papers (1) originate in Europe and the UK, (2) are about MOOCs that are open to the public, and (3) have ICT and programming as focus. There are significant opportunities for doing original research on using STEM MOOCs for science engagement in an African context.

Introduction

Inspired towards Science, Engineering and Technology (I-SET) is an engaged scholarship flagship project of the College of Science, Engineering and Technology (CSET) at University of South Africa (Unisa). The aim of the project is to inspire and engage various interest groups in science, engineering, technology, and mathematics (STEM), mainly through robotics activities. Although the initial project target focus was the learners in robotics teams, the focus has evolved to include the development of a competent core of robotics coaches (including students, educators, and community leaders). The opportunities to train and equip the learners and coaches include face to face workshops, in-person robotics competitions and science exhibitions. The need for alternative modes of STEM engaged scholarship has become more dire, as COVID-19 restrictions enforced social distancing, closed borders, and cancelled in-person engaged scholarship events.

Massive Open Online Courses (MOOCs) allow access to online community education and engagement (with no constraint on the border, continent, time-zone, or public demographics), thus increasing the reach. Whilst technology may be a central aspect of education and engagement (Bond *et al.*, 2020), the specifics of STEM-related education through MOOCs (Majid *et al.*, 2020) may contribute to the enhancement of STEM engaged scholarship. STEM MOOCs were introduced at Unisa to ensure ongoing engaged scholarship. Examples of STEM MOOCs for engaged scholarship include Robotics, Programming, and Cyber Security.

To investigate the effectiveness of the STEM MOOC in terms of impact and reach as presented in the literature, an extensive research project was launched in 2019 to investigate the effectiveness of MOOCs for engaged scholarship for all STEM subjects.

The first phase of the research focuses on understanding the scope of current knowledge on the characteristics of STEM MOOCs that could impact on the effectiveness of MOOCs in terms of mainly learner engagement and retention. This part of the research project focuses on systematic reviews of STEM MOOCs to establish existing knowledge on aspects such as learner throughput, attrition rates, and design aspects. An important aspect is also to understand knowledge gaps and to systematically create research sub-projects to address such gaps.

This paper forms part of the initial phase of the project and contains an exploratory systematic review of STEM MOOC papers in the context of the potential for the use of MOOCs scholarly engagement, specifically for STEM subjects, including (but not limited to) physics, chemistry, engineering, programming, and robotics. This research explores the scope and extent of existing literature of author demographics, subject focus, learner level and the aspect of the MOOC focus (e.g. design, development, content, assessment, learner engagement and throughput, success and attrition). The review considered literature from the start of MOOCs (2008) to 2020. This rest of the paper is structured as follows: The next section presents a literature review (Section 2), then we provide a definition of the research problem (Section 3), we describe the systematic review research methodology (Section 4) and the application of the systematic review methodology in this research (Section 5), we present the research findings and the identification of future research opportunities (Section 6), and finally the research conclusions are drawn (Section 7).

Literature

In this section and related sub-sections, the importance of an understanding of STEM MOOCs for engaged scholarship is argued for. The definition of STEM engaged scholarship and MOOCs are presented from the literature. The application of STEM MOOCs is reviewed, with a specific focus on the subject content, the target audience, and the research focus.

STEM and STEM engaged scholarship

The requirement for quality education, (in this instance STEM education), links to the United Nations' Sustainable Development Goal (SDG) 4 that expresses the ideal of quality education for all (Majid *et al.*, 2020). The importance of quality STEM education for future national socio-economic development has been advocated (Kennedy, 2014; Sharma and Yarlagadda, 2018). Similarly, the provision of good quality STEM education for learners from disadvantaged backgrounds is considered to be important (Xie, Fang and Shauman, 2015). Whilst the technology in STEM may have diverse understandings, the importance of equipping educators in the use of technology in and for education has been highlighted (Ellis *et al.*, 2020).

There are, however, persistent global concerns about whether sufficient individuals with STEM qualifications are produced to meet the economic growth demands, in developed countries (Gonzalez and

Kuenzi, 2012), and in developing countries (Boateng and Kumbol, 2018). This challenge makes it imperative that adequate STEM awareness exists in societies to enable future workers to make meaningful STEM career selections (Magagula and Witten, 2019). Furthermore (Marrero, Gunning and Germain-Williams, 2014) argue that it is desirable for all citizens to have at least a basic level of STEM education, to increase the overall levels of both logic in thinking and critical reasoning in discourses of public interest. Thus, to address the need for STEM participation and understanding, STEM engagement is necessary. STEM engagement requires commitment from at least two parties and is thus an active (rather than passive) process. A STEM engagement strategy is required (Murphy *et al.*, 2019), to address the shortcomings of STEM education in a rapidly changing society and thus enhance STEM education.

STEM engagement has also been heeded as a mechanism to address gender imbalances and inequalities by addressing confidence and motivation aspects of education (Gamse, Martinez and Bozzi, 2017). STEM engaged scholarship may involve workshops, lectures by experts (such as university lecturers) to diverse groups of learners, support for STEM teachers (Gamse, Martinez and Bozzi, 2017), STEM activities such as First Lego League projects (Oppliger, 2002) or summer camps such as iQUEST (Hayden *et al.*, 2011). Many STEM engagements involve the equipping of educators, learners, and members of the public with STEM knowledge and skills required for the 21st century. It thus follows that the STEM engagement requires educators and learners to engage with STEM content.

In our current situation, STEM engaged scholarship is constrained by COVID regulations. However, to ensure that STEM engaged scholarship has reach (to greater communities), alternative engagement media need to be considered. The effectiveness of the media will influence the impact of the STEM engaged scholarship. Within this context the authors are interested in the potential of MOOCs to serve as a channel of scholarly engagement, specifically with the intention of imparting STEM knowledge to learners and educators, which is discussed in more detail in the following section.

MOOC and MOOC participation

Recent developments in technology have enabled new channels to be used for STEM engagement. Examples include mobile technologies (Krishnamurthi and Richter, 2013) and MOOCs (Dasarathy *et al.*, 2014). The focus of this paper is on MOOCs. MOOCs provide access to non-formal education and the ability to reach larger communities and to increase engagement opportunities (Tømte, 2019). (Kennedy, 2014) outlines that MOOCS have being implemented globally as a way of enhancing teaching and learning. MOOCs provide an opportunity to students who might not have resources to enroll in formal education programmes.

Since the socio-economic gap has grown significantly in the past years in Africa, the need for alternative skills solutions is dire (Ng'ambi *et al.*, 2016). In Africa, the massification of access to STEM education is therefore crucially important (Formunyam, 2020). Thus, the use of MOOCs in an African context as one of the ways to massify STEM access is of importance, and the opportunities and challenges afforded by MOOCS in this context need to be carefully considered, well-understood, and explicitly defined.

STEM MOOCs

The intention of this paper is to understand the current state of scientific knowledge around the use of STEM MOOCs. Specifically, the authors are interested in investigating:

- The geographical spread of knowledge on the topic of STEM MOOCs.

- An understanding of the extent to which STEM MOOC research has focused on learner or student groups (for example school learners, students, working persons or the public).
- Given the importance of overall curriculum and educational approaches to STEM education for successful engagement, it is important to understand which aspects of tuition and learning MOOC research has focused on (for example, MOOC design, student engagement, throughput, and attrition).

The systematic overview of existing knowledge will enable the authors to use existing knowledge to improve STEM MOOCS at UNISA to achieve improved impact and reach of engaged scholarship.

Research problem

The research question addressed in this paper is: What is the scope and focus of existing STEM MOOC research that could inform STEM engagement achieve reach and impact?

Research methodology – Systematic literature review

Overview

Because of the nature of the research question, a systematic literature review was selected as the most appropriate research method. The method that was used consisted of the following steps: (1) determination of the research question; (2) determination of search terms; (3) compilation of inclusion and exclusion criteria; (4) selection of databases to be used; (5) searches conducted; (6) screening of papers on the title and abstract, and full text; (7) coding of selected full-text papers. The steps of the method for a systematic literature review are discussed in the following subsections.

Search terms used

The search terms that were used are shown in Table 1. The search focused on the intersection of three main areas of interest, thus MOOCS, STEM disciplines, and engagement. For this paper, environmental and agricultural sciences were not part of the present study.

Table 1 The systematic review terms

Topic String 1	Search Strings
MOOCS	"MOOC*" OR "Massive Open Online Course" OR "Non-formal Education" OR "Informal education"
STEM	"STEM" OR "science" or "physics" OR "math*" OR "engineering" OR "chemistry" OR "astronomy" OR "statistics" OR "programming" OR "computer science" OR "computing" OR "informatics" OR "robotics" OR "AI" OR "artificial intelligence" OR "astronomy" NOT "social science" OR "political science" OR "consumer science" OR "life science" OR "medical science" OR "animal science" OR "geography*" OR "biolog*"
Engagement	"complet*" OR "attrition" OR "engagement" OR "participat*" OR "throughput" OR "success" OR "dropout" OR "retention" OR "experience"

Inclusion and exclusion criteria

Inclusion and exclusion criteria took into consideration the period of existence of MOOCs (2008 onwards), language, and types of publications. The criteria used for this systematic review are presented in Table 2.

Table 2 The inclusion and exclusion criteria	
Include	Exclude
Published from 2008 onwards	Published before 2008
English language	Not in English
Primary, empirical research	Grey literature
Theoretical papers via scholarly databases	Systematic Reviews
Conference papers	
Journal papers	

Databases selected

In consultation with a systematic review software (EPPI) and educational experts, three databases were selected for searching, namely Web of Science, Scopus and ERIC (because of the educational nature of the research).

Extraction process

The steps followed during the extraction process include searching the chosen databases using the search strings shown in Table 1; Exporting search results into the systematic literature review software (EPPI); Exclusion of duplicates; Screening of titles and abstracts for relevance; Uploading full papers; Screening on full papers; Further exclusions; Coding of papers; querying codes. The process is set out In Figure 1.

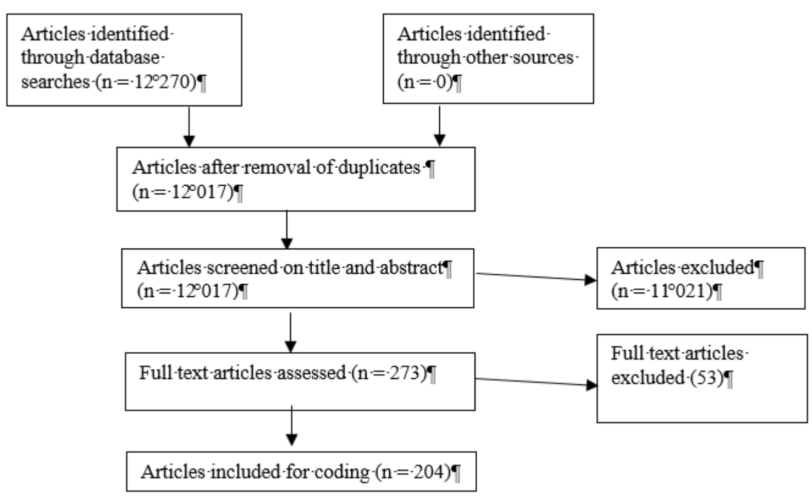


Figure 1 PRISMA Diagram ***(Adapted from** (Moher et al., 2009)**)***

Coding

The intention of the systematic review was to present an overview of the global research activity around STEM MOOCs. The researchers therefore developed a coding system to reflect the activity. The coding included the author demographics, subject focus, learner levels (schools, undergraduate), and the aspect of the MOOC that was the focus of the paper. The coding scheme is shown below in Table 3.

Table 3 The coding scheme for the systematic review	
Author demographics	Africa, Europe and UK, Asia, North America, South America, Australia & New Zealand
Subject focus	Physics, Engineering, ICT and Programming, Astronomy, Mathematics and Statistics, Robotics, STEM generic, Chemistry, Nanotechnology, Other
Student level	School, undergraduates, postgraduates, working persons, general public (no prerequisites), other, more than one group of learners
Aspect of MOOC that was focused on	Design of MOOC, MOOC content, MOOC engagement, completion/attrition, MOOC assessment, evaluation of MOOC quality/success, future proposals for MOOCs, technology, other

Findings

Demography of researchers

The country of research origin for each paper was defined in terms of the country of the first author of the research paper. The country-of-origin coding data is presented in Figure 2.

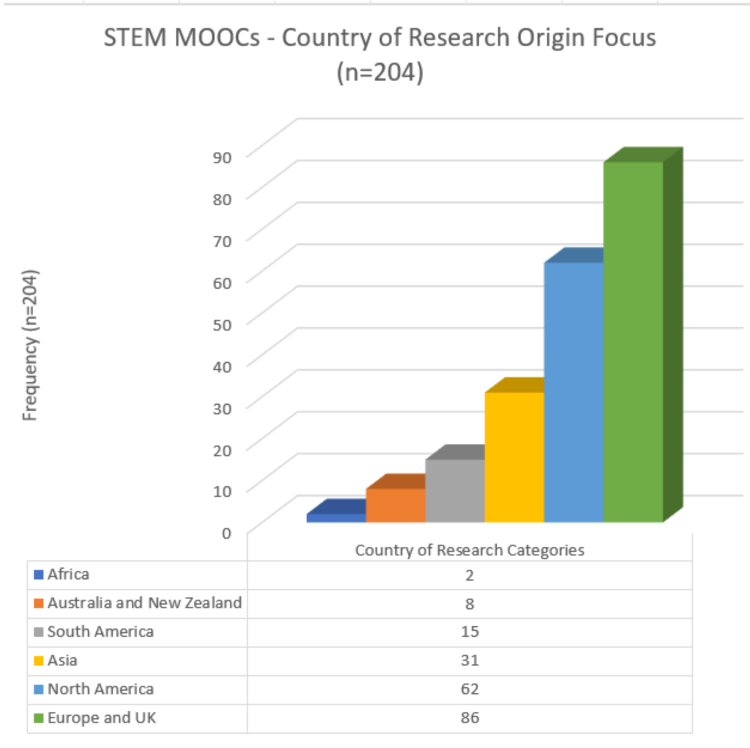


Figure 2 Chart STEM MOOCS - Country of research origin

Figure 2 presents the chart of the country of origin of research coding. The greatest contribution to STEM MOOC research (42%) originated from Europe and the UK. The continent that is least represented is Africa (1%). Given the potential importance of MOOCs for reaching groups in Africa (as highlighted in previous sections), it should be noted that this presents a research opportunity. In general, the developing world seems to be underrepresented in STEM MOOC research (Africa, parts of Asia and South America), which is not unexpected, but this finding highlights the general need for more focused research on STEM MOOCs in developing countries.

Student level focus (target audience)

The student focus was defined in terms of the target audience of the MOOC. However, it was noted in the literature that although some MOOCs were aimed at a more general audience, the pilot MOOC (as described in the literature) was evaluated by a sample of academics or students (graduates or under-graduates). The data from the 204 articles included in the systematic review where coded according to the student level focus. The student level focus coding data is presented in Figure 3.

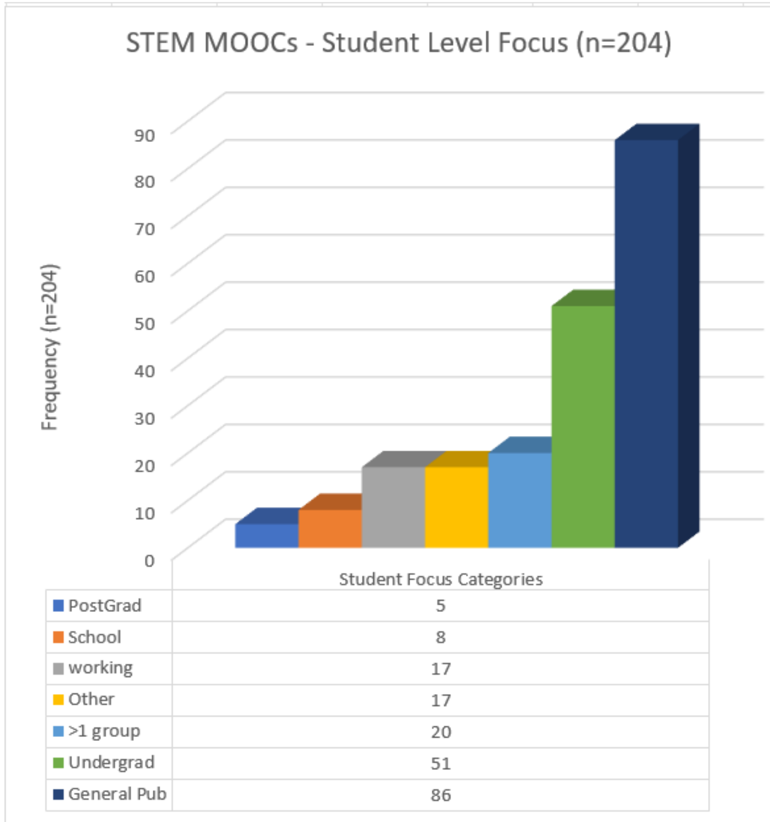
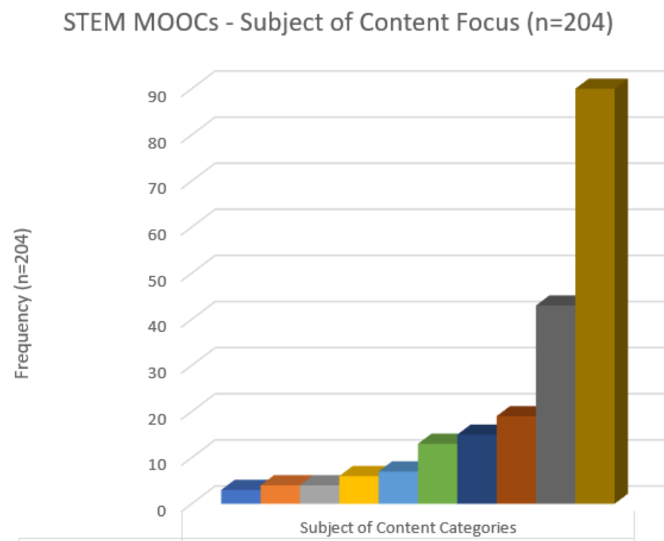


Figure 3 Chart STEM MOOCS - Student Level Focus

Figure 3 presents the level chart of the student focus coding. The greatest part (42%) of the chart is the public. This is as expected, given that MOOCs are defined in terms of open access for all publics. Papers about MOOCS for school learners are limited (4%). Therefore, from a STEM engaged scholarship perspective that focuses on the public, a significant body of knowledge exists around STEM MOOCs that could inform STEM MOOC design for outreach and engagement purposes. However, the limited focus on STEM MOOCs for school children could be an important area for future research, as this group of learners is of crucial importance for STEM engaged scholarship.

Subject of content focus

The subject of content focus of the STEM MOOC papers included in the study is presented in Figure 4.



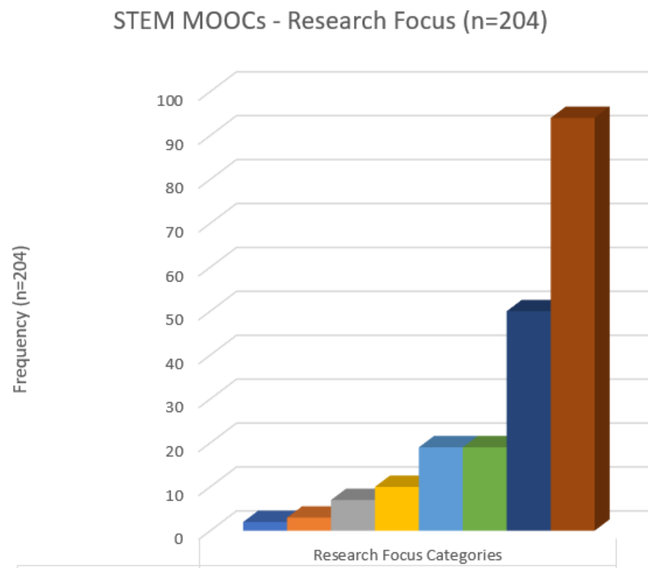
	Subject of Content Categories
Nanotechnology	3
Astronomy	4
Other	4
Robotics	6
Chemistry	7
STEM Generic	13
Physics	15
Mathematics/Stats	19
Engineering	43
ICT/Programming	90

Figure 4 Chart STEM MOOC - Subject of content focus

Figure 4 presents the chart of the coding of the subject of content focus of the MOOC. Note that this is for knowledge domains within the STEM knowledge domain. The greatest number (44%) of papers focus on ICT and programming as subject area. The subject contents that are least focused on in the systematic literature review are nanotechnology (1%) and astronomy (2%). The growing domain of robotics is also very limited at 3%.

STEM MOOC research focus

The data from the 204 articles included in the systematic review were coded according to the focus of the MOOC research. The focus is presented in Figure 5.



	Research Focus Categories
MOOC Content	2
Other (multiple focus)	3
MOOC Assessment	7
Completion/Attrition	10
Evaluation of MOOC qaulity/success	19
Technology	19
MOOC Engagement	50
Design of MOOC	94

Figure 5 Chart STEM MOOC - Research focus

Figure 5 presents the chart of the coding of the focus of the MOOC research. Most papers (46%) focus on the design of MOOCs. The aspect that is least focused on in the systematic literature review is MOOC content (1%). It is noted that MOOC completion rates remain a significant focus and are considered an important aspect of MOOC design. The important aspects from a STEM engagement perspective (such as completion/attrition rates, evaluation of MOOC success, and student engagement with MOOCs) all seem to be under-researched and would point to research opportunities to better understand the impact of MOOCs as a channel for STEM engagement.

Conclusions and future research

MOOCs represent an opportunity for STEM engagement and engaged scholarship, especially in the current reality where physical engagement and contact sessions are restrained. A significant body of research exists on STEM MOOCs, with the foci of the existing research being largely ICT and programming, MOOCs for the public and undergraduate students, and the design of MOOCs in Europe and North America.

For STEM engagement in Africa, important gaps in existing research would include the lack of STEM MOOC research in Africa, the sparse information on MOOCs for school learners, limited information on important aspects of MOOCs such as completion/attrition factors and learner engagement factors, and the limited focus on important STEM areas such as mathematics, physics, astronomy, and robotics, to name but a few. These gaps represent interesting and important future research areas.

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Integrating Virtual Mentorship Into SAASTA's Role Modelling Programme

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Abstract: Virtual communication platforms brought by the advent of information and communications technologies (ICTs) could create an enabling environment for learners to have access to their Mentors/Role Models. This will require the utilisation of virtual mentors/role models in the STEMI Role Modelling programme. Although virtual mentoring is not a new concept, it is not a phenomenon that has been universally explored for rural STEMI related learners. In this regard, it is important to investigate the effectiveness of integrating virtual mentors/role models into the SAASTA's STEMI Role Modelling programme for the historically disadvantaged participants.

Key Words: *Mentor, STEMI, Virtual Mentor, SAASTA, Science Education, Learner(s).*

1. Introduction

The South African Science and Technology Advancement through its Science Education Unit has established a career profiling and mentoring project which exposes learners to information on various fields of studies and careers in the science, technology, engineering, mathematics and innovation (STEMI) sectors. SAASTA has over the years created a platform through which learners are exposed to workshops, the industry and professionals in the STEMI related fields including role models to encourage them to take up maths and science subjects at schools and ultimately direct them towards careers in STEMI related fields. The role models project in particular focuses on involving professionals, graduates or students who originate from the learner's community or the surrounding for the learners to be able to associate and relate with them.

Educational non-government organisations like the Gallery of Academic Leaders (GOAL) and Capricorn Educational Resource Centre (CERC) based in Limpopo province are also involved in mentorship and motivational programmes that are aimed at assisting learners from rural communities. Through their programmes, GOAL and CERC focuses on providing support to learners and entry-level tertiary students through mentorship, outreach programmes, motivations, tutoring and career guidance.

However, due to some of the professionals or graduates associated with these organisations no longer residing permanently in those communities due to work or academic commitments, the supply of the mentors to the learners may face challenges such as; time constraints for the Mentors/Role Models, lack of continuity between the learner and the Mentor as well as difficulty in sustaining the Mentor and Mentee relationship. Learners would sometimes lose contact with their Mentors due to distance or the other way round. In this study,

1.1. Research objective

The main objective of this study is to investigate whether the integration of virtual mentorship platforms can assist in addressing accessibility and communication challenges faced by mentors and mentees who participate in the GOAL and SAASTA's mentorship and role modelling projects.

1.2. Research problem and research question

This paper will identify and analyse the research problems. The research question will also be addressed during the data collection and analysis processes, which also includes amongst others the theoretical framework, literature review and the conceptual framework.

1.2.1. Research problem

The main research problem is the accessibility and communication challenges faced by mentors and mentees who participate in the GOAL and SAASTA's mentorship and role modelling projects.

1.2.2. Research Question

The main research question will be "How can the use of virtual mentoring platforms address the accessibility and communication challenges faced by mentors and mentees who participate in mentorship and role modelling projects?". In order to answer this question, a questionnaire with a list of qualitative and quantitative questions was developed and distributed to the participants from both organisations.

2. Review of the literature

The effectiveness of virtual mentoring with the objective of improving youth outcomes seem to have varying views from the different segments of the society. In addition, virtual mentoring provide more flexibility for both learners and their mentors. Kaufman (2017) states that virtual mentorship has both positive and negative impact on the mentor and the mentee. However, due to the limited number of studies that have been conducted in the field of virtual mentoring, it is difficult to draw conclusions about its effectiveness in general. In order to address this challenge many institutions or organisations are now developing a virtual mind-set as technology continues to play a significant role in e-mentoring and is used as a way of connecting the mentees with their role modelling partners or Mentors.

According Figueroa (2017) virtual mentoring involves the use of a computer interface that provides the ability to connect with another party. This engagement could be in the form of text base exchanges, audio, video or any combination. Therefore, it is important to investigate the effectiveness of utilising virtual mentoring platforms for SAASTA role modelling projects.

2.1. The concept of mentorship and role modelling

Both mentorship and role modelling plays a significant role in the development of young people, therefore, before understanding the nature of virtual mentorship or role modelling it is important to first understand mentorship or role modelling.

Firstly, in the mentor/mentee relationship the mentor is expected take responsibility to facilitate the success of his/her mentee(s) by listening with care and providing information, advice, encouragement, support, honest feedback, and access to networks to assist them. In the mentor/mentee relationship, the mentees are expected to play their role by being honest with their mentors about what is going well and what is not going well or needs attention and also to be organised and spend sufficient time required to build a productive relationship with their mentors.

Secondly, role modelling is can be described as a process that allows students to learn new behaviours without the trial and error of doing things for themselves. This include the facilitation of peer relationships, development of increased skills, provision of individualised one-to-one teaching and opportunities for experiential learning and also the offering of help with problem solving.

2.2. The evolution of virtual mentorship

The emergence of virtual mentorship was brought by the evolvement of technological advancements have over the past two decades impacting how the students and instructors acquire and deliver information amongst each other. There has been a rapid growth in diverse technology-mediated forms of communication in both formal and informal contexts. For example, virtual mentoring gained momentum in the 1990s when the online exchange programmes such as e-mails has become more widespread.

2.3. The characteristics of virtual mentorship

According to Knouse (2001), virtual mentoring refers to learners interacting with their mentors on the online platform such as the internet. Virtual mentoring is characterised by the use of a computer interface that provides the ability to connect mentors and mentees through platforms such as instant messaging, and related technologies, and such interfaces have changed the way we communicate. For example the engagement can happen in form of text-based exchanges, audio, video or any combination.

The functions received in e-mentoring relationships parallel those found in traditional relationships and include career development (coaching, sponsoring, increasing exposure and visibility, and offering protection), psychosocial support (offering acceptance and confirmation, providing counselling and friendship), and role modelling. E-mentoring requires some form of information and communication technology (ICT), such as an Internet-connected computer, smartphone, or tablet.

The advantages and the disadvantages of virtual mentoring are be discussed below.

2.4. Pros and cons of virtual mentorship

According to Kaufman (2017), the effectiveness of virtual or e-mentoring seems to have varying views mainly due to the limited number of studies in the field of virtual mentoring and that makes it difficult to draw conclusions about its effectiveness in general. Some of its impacts are good, whilst on the other side the impact is close to nothing Kaufman (2017). The pros and cons of virtual or e-mentorship are elaborated below.

2.4.1. Advantages of virtual mentorship

One of the pros of this method is that it provides more flexibility. According to Williams, Sunderman and Kim (date?), virtual mentoring does not provide for greater flexibility in regards to time. Virtual mentorship is also not place dependent, as it does not require that the mentor and the mentee live within close proximity to each other, as does face-to-face mentoring.

2.4.2. Disadvantages of virtual mentorship

Challenges to e-mentors have been identified in communication, technology use, and determining the mentor role. Other challenges related to e-mentoring include the reluctance to accept virtual worlds as educational tools, lack of resources, lack of ICT knowledge/skills, elimination intimacy bond between the mentor and the mentee. Furthermore, Greg, Galyardt, Wolfe, Moon & Todd (2017) regards matters relating to online security, privacy, and intellectual property rights concerns as some of the main challenges facing the development of virtual mentoring.

3. Theoretical Framework

For the purpose of this study, a number of theories relating to communications and mentoring schools of thoughts will be identified, analysed and applied in relation to the topic being investigated. The mentoring theories that will be analysed includes the Social Learning theories, the Zachary's Four-Phase Mentoring Model and the Critical Theory of Communication Technology and will also be applied in this study.

3.1. Social Learning Theory

The social learning theory is one theories used in this study mainly because it is based on the notion that people from their interactions with other in a social context. This is relevant to this study mainly because the mentee are likely to learn from their interactions with their mentors. In addition, the theory highlights that people learn by observing the behaviours of others, and thereafter assimilate and imitate that behaviour, especially if their observational experiences are positive ones or include rewards related to the observed behaviour.

For programmes such as the SAASTA's role modelling and GOAL's mentorship programmes, it becomes challenges for learners to learn through observation as most of the mentors are not located within close proximity to each other. However, based on one of the general principles (Modelling) of the social learning theory, process of learning can happen through exposure to new influential or powerful [role] models. In most cases, engagements between mentors/role models and learners happens once off or once in a while, depending on the availability of the mentors, therefore, exposing learners to mentors remains key to their learning process.

Role modelling or mentorship should not be taken as a one way process whereby the mentee or the learner only depends of the role model, but a two-way relationship in which both play an integral part in the mentoring process.

3.2. Zachary's Four Phase Mentoring Model

One of the widely used models of mentoring includes the Zachary's Four Phases model which indicates that a mentoring process is made up of four phases that are dependent one another to form a developmental sequence. Mentoring as described Zachary, is an educational approach to impart new knowledge, skills, attitudes and competencies.

Mentoring practice has shifted from a product-oriented model, characterized by transfer of knowledge, to a process-oriented relationship involving knowledge acquisition, application, and critical reflection. Below are the Zachary's mentoring model phases:

3.2.1. Preparing

This is regarded as the soil tilling the before planting. In this phase, both the mentor and the mentee starts preparing for their mentoring relationship as this helps to create the fertile soil for embedding the mentoring relationship and adds value to the mentoring partnership.

3.2.2. Negotiating

This is the seed planting phase whereby the mentoring partners reach agreement on learning goals and define the content and process of the relationship.

3.2.3. Enabling

Once the relationship goals between the role model and the mentees, the process of ensuring that there is sustainable growth begins. The enabling phase takes longer to complete than other mentoring phases, for this is when the greatest learning between mentoring partners takes place.

3.2.4. Closure stage

At the beginning of the relationship, the mentoring partners begin to plan about closure, this involves establishing which objectives needs to be fulfilled by the mentoring relationship. Zachary defines closure an evolutionary process, which actually starts in the negotiating phase when mentoring partners establish closure procedures. During the coming to closure phase, mentoring partners implement their exit strategy.

In recent times, role modelling or mentoring can be conducted via online platforms; therefore, it is important to look at the role of communication technology in the mentoring processes.

3.3. The E-Mentoring Model

According to Rowland (2012), technology plays a significant role in e-mentoring and bridges the relationship established between both the mentor and the protégé. For example, the model for e-mentoring framework operates using three dimensions based on the content . Firstly, e-mentoring can be completely virtual or a blend of face-to-face and virtual aspects. Second, e-mentoring can be informal in that a mentor and protégé find each other and the relationship grows organically, or the relationship can be arranged in a formal mentoring program. Third, different processes can match mentors and mentees. Based on the e-mentoring model developed by Neely, Cotton & Neely, (2012) the e-mentoring process involves the use of various communication channels, which leads to the fulfilments of the training needs of the mentee.

Below is the graphic representation of Neely, Cotton & Neely (2012) e-mentoring process

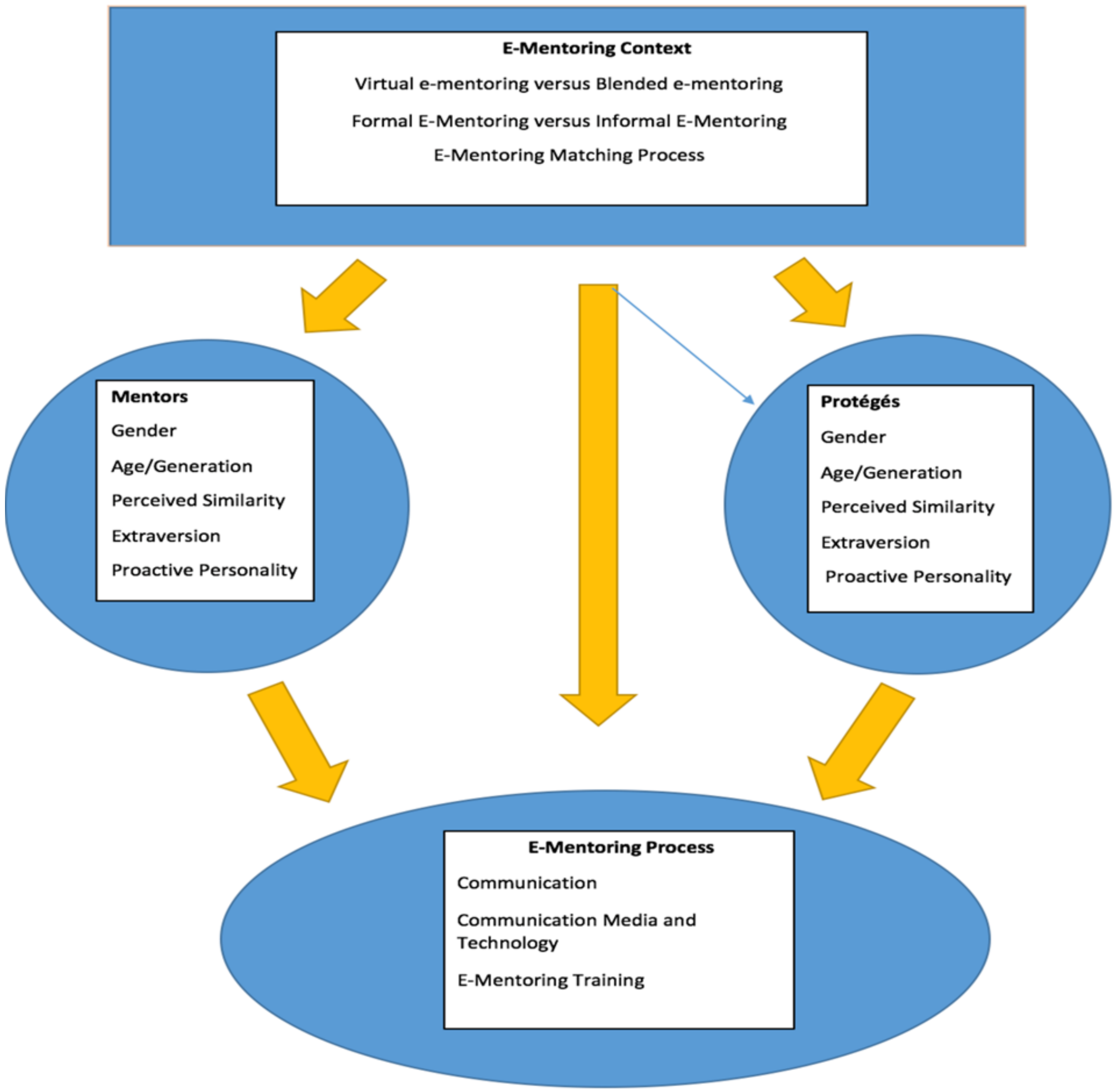


Figure 1: E-Mentoring Model

The above models or theories have indicated that role modelling or mentorship should be regarded as a relationship between a mentor/role model with the mentees. Both needs to benefit from the role modelling relationship. It also indicates that technology plays a significant role in virtual mentoring.

4. Research methodology

The qualitative research approach will be used in this study mainly because the purpose of this study is to investigate whether the integration of virtual mentorship platforms can assist in addressing accessibility and communication challenges faced by mentors and mentees who participate in the GOAL and SAASTA's role modelling programmes.

In an ideal world, one would want to collect data from all the participants who are involved in the role modelling programmes, however, it is unlikely that all the participants can be involved in the study because of time and human resource constraints. Therefore, a sample representative of members from GOAL and SAASTA's aligned Capricorn Educational Resource Centre was selected.

4.1. Sampling

According to Baran and Jones (2016), sampling is one of the critical components of any research study and therefore it is important for the researchers to carefully decide on who to include as participants as part of the design process. There are various sampling methods that can be utilised by the researcher when selecting the participants. For the purposes of this study a purposive sampling method was utilised whereby selected participants were identified from two organisations namely, Gallery of Academic Leaders and the SAASTA's aligned Capricorn Educational Resource Centre in Capricorn District Municipality, Limpopo province. The participants were identified through their involvement in the mentorship or role modelling programmes.

4.2. Data Collection

In order to achieve the objectives of this study, data collected was conducted through the use of open ended questionnaires with participants who are involved in the GOAL and SAASTA's role modelling/mentoring programmes. The collected data was then sorted in order to come up with the results stipulated below.

5. Results

The results for this impact study are sorted based on the following categories:

5.1. Participation in the role modelling/mentoring programmes

The main participants in this study were members from two educational non-profit organisations namely GOAL and SAASTA's aligned Capricorn Educational Resource Centre. Both organisations have ongoing role Modelling or mentorship programmes and a depended mainly on volunteers to implement these programme. Most of the volunteers have indicated that they have been involved in the role modelling/mentoring programmes for a minimum of two years or more.

Most of those volunteers includes young working professionals, graduates and postgraduate students and a programme like virtual mentoring can assist in balancing their academic or professional commitments with their mentorship responsibilities.

"This will also help me to manage my activities more efficiently and strike a balance between work and family commitments with role modelling responsibilities" Respondent 1.

The above sentiments from the respondent are supported by Hansen who indicates that virtual mentorship is not place independent as it does not require that the mentor and the mentee live within close proximity to each other, as does face-to-face mentoring. In addition, Rowland (2012), states that technology plays a significant role in e-mentoring and bridges the relationship established between both the mentor and the protégé.

5.2. Perception of role modelling/mentorship programmes

Four out of the seven participants agreed while three strongly agreed that virtual mentorship was relevant. None of the participants disagreed that virtual mentorship was relevant, flexible and exposes learners to their mentors. All seven participants indicated that they are willing to be involved in multiple engagements with the learners via virtual platforms.

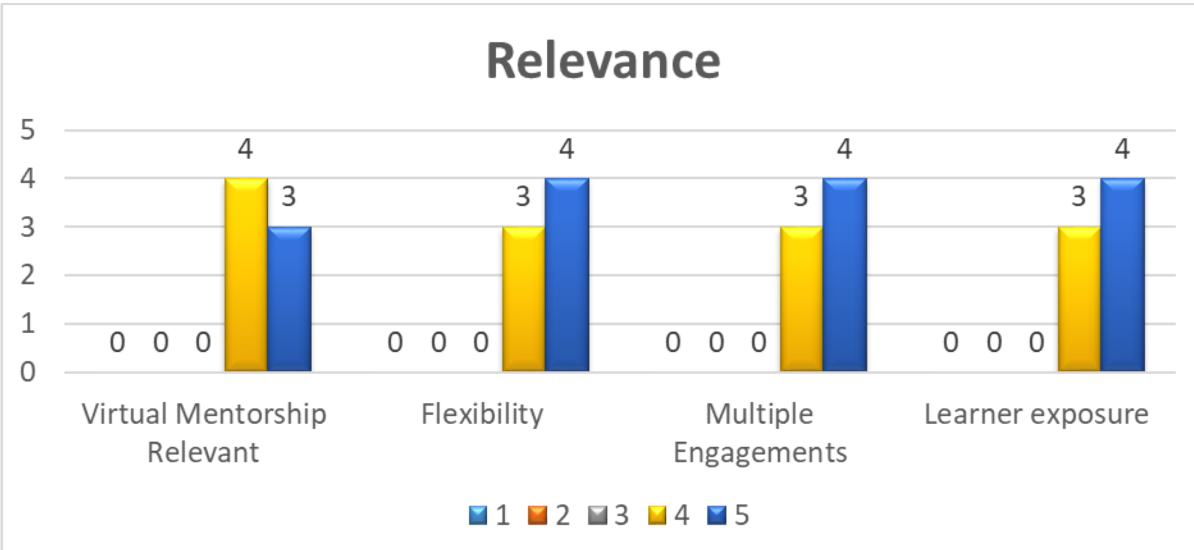


Figure 2: The relevance of virtual role modelling/mentorship programmes

The participant also provided their own views with regard to the integration of virtual mentorship into role modelling programmes.

Below is one of the verbatim quotes from the respondents:

"Due to time constraints and shortage of resources to always travel to different schools, it is often difficult to maintain contact more frequently post the role modelling campaigns. Information and communication technologies will help to enhance the connection in a sustainable manner." Respondent 2.

The above respondent raised concerns related to time and is of the view that ICTs can play a major role in ensuring that the relationship between the mentor and the mentee is maintained. This is confirmed by Williams, Sunderman and Kim, (date?) who indicates that virtual mentoring programmes provides for greater flexibility in regards to time.

5.3. Sentiments from participants

There was consensus between the participants on their willingness to engage with learners post the role modelling campaigns as they believe that learners requires more exposure to human and technical resources in order to make communication easier between the mentoring partners.

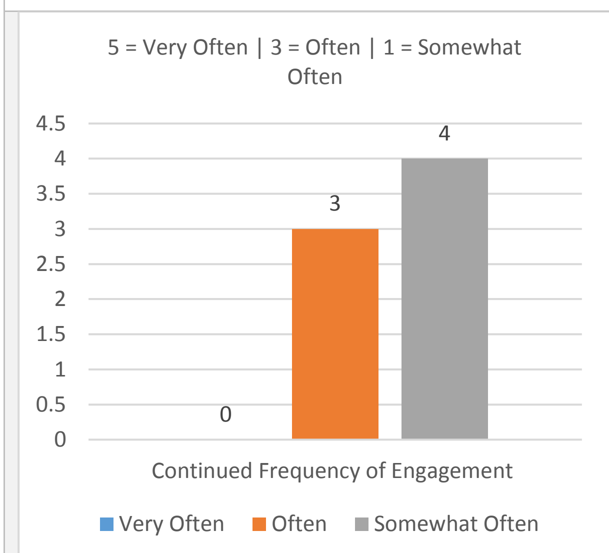
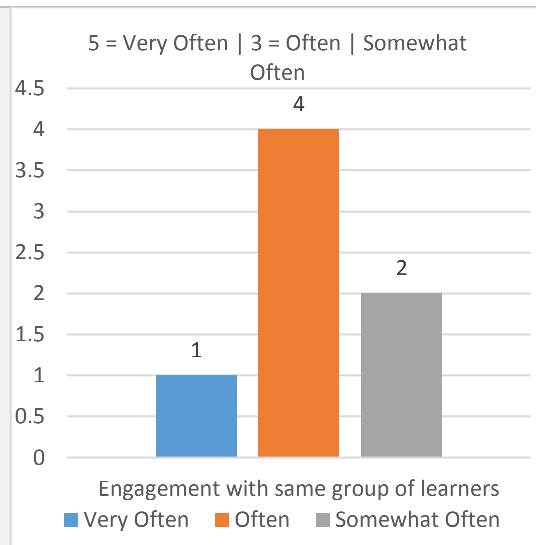
"If learners can be exposed to things like tablets, pc and wife connection, it will be easier for them and us as mentors. " Respondent 3

The above statement shows that the participant is of the view that ICTs can assist in enhancing engagement between role models and the learners, which will in turn expose them to their mentors. The process of learning can happen through exposure to new influential or powerful [role] models as described by Nebavi in his analysis of the Social Learning Theory.

Furthermore, the participants highlighted that online platforms can help their participation in role modelling/mentorship campaigns and would recommend virtual mentoring to other mentors.

5.4. Frequency of Engagement

The participants were asked how often they have engaged with the same group of learners as part of their role modelling /mentorship responsibilities. Based on the scale of 1 -5, four out of seven participants rated their engagement at 3, while the participants three rated at 1, meaning their engagement was below average.

Figure 1) How often have you engaged with the same group of learners as part of your role modelling responsibilities?	*Figure 2: How often do you continue to engage with the learners even after the role modelling campaigns events?*
	

Only one participant indicated that they have had continued engagement very often with the same group of learners.

5.5. Challenges

Below are some of the challenges highlighted by the participants with regard to their involvement in the role modelling or mentorship programmes.

5.5.1. Access to venues

The participants indicated that they have limited access to venue required for them to engagement with the learners.

5.5.2. Lack of resources for learners such as:

i. Computers: The participants indicated that they have limited or no access to resources such as computers with webcam and internet connection.

ii. Internet Connection: The participants indicated that they, together with the learners have challenges related to data bundles affordability as they need internet connection for live streaming videos or access Youtube videos for motivational and educational purposes.

iii. Access to smartphones: One of the main challenges raised was the learners' limited access to smartphones to enable regular engagement via instant messaging platforms such as WhatsApp.

6. Findings, Conclusion and recommendations

6.1. Analysis of Findings

6.1.1. Adoption of online technologies

The first fining from this study was that there is slow progression in the adaptation and use of online technologies into mentorship and role modelling initiatives. This has in turn had an impact on the continuation of the mentor and mentee relationship. There was a consensus that the adoption of online technologies into the programme can help improve the contribution or involvement by the mentees.

6.1.2. Integration of virtual platforms

Most of the participants are in support of the integration of online/virtual platforms into role modelling/mentorship programmes. Due to challenges related to the logistics of travelling between the mentor and the mentee's different locations, the mentor and the mentee often have limited time to engage, thus affecting

6.1.3. Lack of infrastructure

As much as there was willingness from the mentors to continue providing mentorship to the learners and entry level tertiary students, limited access to communication infrastructure such as internet connectivity, mobile and video streaming devices

6.2. Conclusion

Mentoring and exposing learners to key information about STEMI study field and career prospects are some of the ways that can be used to encourage learners to consider enrolling in STEMI related subjects at a young age.

6.3. Recommendations

Below are the recommendations guided by the results from the data collected, literature review and the theoretical framework utilised in this study.

The Integration of virtual mentorship platforms into role modelling/mentorship programmes needs to be considered. SAASTA should consider integrating ICTs into its mentorship and role modelling campaigns. This will include the resourcing of the mentors with adequate ITC equipment. Mentors/role models need to be equipped with ICT skills. the ICT skills such as the ability to host tele-conferences and virtual presentations can help the mentors in when facilitating their virtual mentor/mentee sessions.

Students/unemployed Mentors should be provided with assistance to cover their internet connectivity (data) costs. Due to high costs of data in South Africa, the mentors should be reimbursed for the costs incurred while doing SAASTA related work, especially when it comes to the hosting of online mentor/mentee sessions. Learners must be provided with group-use devices such as laptops/tablets. Due to limited resources available, learners from the same area could be provided with share devices such as laptops or tablets to use when engaging with their mentors virtually. The devices should be kept at a school or a science centre.

There should be a consideration to develop dedicated online applications or platforms for mentorship programmes. The use of zero-rated online mentorship application should be considered. This approach will save costs for both learners and mentors. Lastly, investment need to be made into the development of virtual engagement infrastructure such as presentation tools, subscriptions and conferencing tools.

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Are Olympiad training programmes effective? Interrogating learners' views on a Mathematics Olympiad training programme:

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***Abstract**: Participation in Mathematics and Science competitions form an important part of a learner's development in these subjects. However, not all learners participate in these competitions while at school. There is a need to increase the participation of learners in these competitions from all schools across South Africa, especially those located in the so-called "disadvantaged" areas. Participation in these competitions may encourage learners to take up high level careers in Engineering and the Sciences. This paper focuses on an initiative to support learners in preparation for round 1 and beyond of the South African Mathematics Olympiad (SAMO). The programme (called the Siyanqoba Mathematics Olympiad training programme) consisted of six intensive sessions where learners were given tutoring support in problem-solving and exposure to a wide range of Olympiad type problems. At the end of the programme, learners were surveyed, using questionnaires, on a number of issues on Mathematics and Mathematics Olympiads as well as their experiences in the training programme. This paper interrogates the views of the learners and also includes analyses of their performance in round 1 of SAMO. The findings at the end of the paper, written with the research question and sub-questions in mind, provide some interesting insights into the training programme.*

Introduction and background

There are various Olympiads and competitions in South Africa. These Olympiads cover a wide range of Science and other subject fields. The author has observed that most of the learners, who participate in these competitions, come from quintile 4 and 5 schools. Participation of learners from other schools needs to improve.

There are certain factors which contribute to the popularity of Mathematics Olympiads and competitions in some schools. Some of these factors, which feature in a paper by Govender (2014) are:

- The role of the teacher in promoting Mathematics Olympiads
- The learning culture of the school where participation in Mathematics Olympiads has become part of the school programme
- Learner performance in school mathematics

- Participation in team events
- Involvement of parents

As far as long-term planning is concerned, there is a need for provinces and education districts in South Africa to advocate for and promote learner participation in Mathematics Olympiads and competitions. However, there is a need in the short term, to increase the pool of learners that participate in Mathematics Olympiads. In this regard, more learners from, especially, quintiles 1 – 3 schools should be encouraged to take part in these Olympiads. The author has found that despite calls for teachers to take the lead in promoting Mathematics Olympiads at their schools, such support seems to be lacking.

The author firmly believes there are learners in all schools who have the necessary potential to participate and excel in Mathematics Olympiads. However, there are certain difficulties associated with the inclusion of problem-solving as part of classroom activities in Mathematics and this may affect learners' enthusiasm for Mathematics Olympiads and competitions. Some of these difficulties are:

- Teachers are not usually comfortable with problem-solving activities
- Learners may become insecure when working with more "difficult" problems
- There is not enough time for problem-solving and it takes too long to teach
- There may be challenges when working with below average mathematics learners
- It requires a lot of preparation on the part of the teacher

(Difficulties of teaching problem solving, 2010)

Despite these difficulties there are several benefits of problem solving. Some of these are listed below::

- Learners are able to develop mathematically using their current knowledge
- It is an interesting and enjoyable way to learn mathematics
- It is a way to learn new mathematics with greater understanding
- It produces positive attitudes towards mathematics
- It teaches thinking, flexibility and creativity
- Children are able to learn general problem-solving skills
- It encourages cooperative skills.

(Benefits of problem solving, 2010)

While it is agreed that there are difficulties in teaching problem solving, the benefits to learners should outweigh these difficulties. In this regard, it is now opportune to discuss the Siyanqoba Mathematics Olympiad training programme. These details were obtained from the South African Mathematics Foundation (SAMF) website (SAMF, 2019a).

The Siyanqoba Mathematics Olympiad training programme

The Siyanqoba Mathematics Olympiad training programme was introduced by the South African Mathematics Foundation (SAMF) to assist learners, especially those from disadvantaged backgrounds, with training and support in preparation for the South African Mathematics Olympiad (SAMF, 2019a).

Siyanqoba means "to conquer" so that everyone should be given an opportunity to move forward in their career or organisation, and in their personal development. In a mathematics context, it means that learners should move forward in their mathematics development through organised training and so provide them with an opportunity to successfully participate in the South African Mathematics Olympiad (SAMO).

The Siyanqoba Mathematics Olympiad training programme is an outreach programme for high school learners throughout the country who show particular ability and interest in mathematics. It concentrates on developing problem-solving skills, unlike in regular school curricula where the focus is more on solving routine-type questions. The programme emphasises the understanding of mathematical concepts rather than pure memorization of formulae. It covers enrichment material which is not necessarily in the school curriculum and aims to improve our competitiveness internationally (SAMF,2019a).

Aims of the Siyanqoba Mathematics Olympiad training programme

The Siyanqoba training programme, which attempts to provide challenging and enriching mathematics activities for top learners and learners with potential, has the following aims (SAMF, 2019a):

- Motivate learners to improve their learning of mathematics; in particular to develop higher order thinking skills and problem- solving techniques.
- Develop learners' interest in Mathematics.
- Development of lateral thinking skills.
- Allow a number of high achieving local learners to take part in mathematics competitions and hence to raise the standard of local school mathematics.
- Improvement of performance in competitions.
- Develop talent which has been identified through the SAMO.

Impact of the Siyanqoba Mathematics Olympiad training programme

The Siyanqoba Mathematics Olympiad training programme intends to have an impact on three key areas. . These are:

- The improved performance of black learners in SAMO and other competitions.
- To have more learners registering mathematics in secondary schools.
- To have more learners following the STEMI careers.

There are currently 12 Siyanqoba centres situated all over South Africa. This study focuses on one centre, which is situated in an urban area of the Eastern Cape.

Literature Review

This short literature review focuses on problem-solving and mathematics competitions. The basis for most mathematics problem-solving research for the secondary school is Polya (1973). Polya proposed four phases in problem-solving: ***understanding the problem, devising a plan, carrying out the plan*** **and** ***looking back*** .In his four-phase plan and other works, he suggests a list of strategies, which include the following:

- draw a figure or table
- look at simpler cases to search for a pattern
- modify the problem (replacing given conditions by equivalent ones)
- exploit related problems (simpler problems, auxiliary problems, analogous problems)
- work backwards
- argue by contradiction or contrapositive
- decomposing and recombining
- generalising
- specialising

Subotnik, Miserandino and Olszewski-Kubilius (1996) state that deep commitment and interest in mathematics begins in the early grades (elementary school) where students who are exposed to concepts and topics beyond computation get a much more complex and accurate picture of the discipline. Teachers who are well prepared and confident in their mathematical learning can enjoy and model creativity in problem finding and solving in their students. While this changes when children begin their engagement with abstract reasoning in mathematics in the later grades, Subotnik et al (1996) report that those with a rich elementary school experience should be able to adapt well to the challenge.

One of the main goals of mathematics competitions is to enrich the study of mathematics (Engelbrecht and Mwambakana, 2016). Bright students need challenges to keep their minds actively focussed on mathematics and prevent them from moving to endeavours outside mathematics which they may find more appealing. For students with less motivation, challenging mathematical tasks can serve to attract them to mathematics learning rather than to the mastery of algorithms or routine methods. In this regard, Powell, Borge, Fioriti, Kondratieva, Koublanova and Sukthankar (2009) also report that even the learning of routine material can improve when taking place in a challenging environment.

The South African Mathematics Foundation (SAMF), in its website, discusses the importance of Mathematics competitions and the resultant enthusiasm and curiosity generated for Mathematics as a school subject. It also states that *"Mathematics is about thinking and the discovery, and validation, of problem-solving methods".* In this regard learners participating in Mathematics competition stand to gain in the following ways:

- Participants in Mathematics competitions will be challenged by the problems and this will help improve their problem-solving skills.

- Problem-solving skills can be further improved by carefully working through the solutions of the competitions.
- Alternative and innovative solutions are given and the problems could be used in classroom discussions on problem solving.
- There is a need for creative problem-solving skills in today's technically oriented market place and expert problem solvers are needed. Practice in problem-solving will help to train our future leaders of technological development. (SAMF, 2019)

This literature review may be summarised as follows:

- Polya's four phase plan and his list of problem-solving strategies are very important when introducing problem-solving in classrooms and exposing learners to Olympiad type problems
- The interest in problem-solving can start in the early grades at school. This would depend on the confidence and preparedness of the teacher. Children with a solid foundation in mathematics problem-solving are likely to adapt to the challenges posed by more abstract mathematics in the later grades.
- One of the main goals of mathematics competitions is to enrich the study of mathematics. While competitions are more suited to the top learners, other learners are also likely to benefit from participating in mathematics competitions
- The South African Mathematics Foundation discusses the importance of Mathematics competitions and the resultant enthusiasm and curiosity generated for Mathematics as a school subject. It states that learners participating in mathematics competitions stand to gain in a number of ways

Research Question

In the light of the previous discussions on the Siyanqoba Mathematics Olympiad training programme and the literature review, the following research question was posed for this study:

> *To what extent does the Siyanqoba Mathematics Olympiad training programme impact on learner performance in round one of the South African Mathematics Olympiad (SAMO)?*

The following subsidiary questions were formulated within the context of this research question:

- What does the Siyanqoba Mathematics Olympiad training programme consists of?
- What are the views of learner participants in the Siyanqoba training programme on Mathematics and Mathematics Olympiads?
- How do learner participants in Siyanqoba Mathematics Olympiad training programme (in one centre) view the training programme?
- How do the responses by learners correlate with their actual performance in round one of SAMO?

Theoretical framework

This study has both an ontological and epistemological basis (Cohen and Manion, 1985). The names of top mathematics learners as well as learners with potential were submitted by schools in response to a letter sent by the writer. It would be fair to say that learners who comprised the sample for this study, were some of the better mathematics learners at their schools. These learners had registered for the South African Mathematics Olympiad (SAMO) and wanted training and tutoring support in preparation for round 1 of the Olympiad. These learners probably had views on a number of aspects with regard to Mathematics and Mathematics competitions. This forms the ontological basis for this study. The process of finding out what these experiences and views are is in line with the epistemological basis of this study which is to comment on the effectiveness of the training programme in which these learners participated.

This study involved the training and development of learners to give them experience in working with Olympiad type problems. In this regard, Vygotsky's "Zone of Proximal Development" (ZPD) has relevance. ZPD is described as the distance between the level of development of a child (when working alone on problems) and his or her level of potential development when working with an adult. The adult is the one driving the learning until the child is able to internalise the knowledge ((Vygotsky, 1978). The leaners who joined the training programme described in this study, may have had some difficulty when working alone with Olympiad type problems. However, with their participation in the training programme where there was a facilitator or tutor (the adult as described by Vygotsky) giving them tutoring support, there may be some positive impact on how these learners work with Olympiad type problems.

The Enrichment Triad Model (ETM) (Renzulli, 1977) is also relevant to this study. This model consists of three different kinds of interrelated forms of enrichment activities that are integrated as a complement to the regular curriculum. Of these three types, type I enrichment activities are relevant to this study. These activities consist of general exploratory experiences that are designed to expose students to topics and areas of study not ordinarily covered in the regular curriculum.

Thus, an appropriate framework in which to locate this study would be "***learner training and development within a mathematics enrichment context***".

Research Methodology

The study involved a mixed- method approach and involved the collection of data over a six week period prior to round 1 of the South African Mathematics Olympiad (SAMO) in 2018. Both quantitative and qualitative data were collected during this period. The quantitative data was the learners' marks in their last three mathematics exams as well as their performance in the first round of SAMO. Qualitative data was collected from the actual programme. This involved observing participants working out problems and a survey of the learners, via questionnaires, at the end of the six- week period. The questionnaires sought the following details from the learners:

- Their views on mathematics as a school subject
- Their last three mathematics exam marks

- Why they participate in Mathematics Olympiads
- Why they joined the training programme
- Teaching in the programme and practice for round
- Highlights and challenges in training programme

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Research sample

The sample consisted of 30 learners from different schools in an urban area of the Eastern Cape. These learners were in grades 10 – 12. Of the 30 learners, 14 completed the questionnaires at the end of the six week period. Learners participated voluntarily in this study; they were given the assurance that all information given by them will be treated as confidential.

Results

The training programme and attendance

The training programme and attendance is shown in table 1 consisted of the following sessions:

Table 1: Training programme and attendance

Session	Activities	Attendance
1	Selection test & review of basic concepts	23
2	Problems from training manual	20
3	Problems from training manual	20
4	Problems from training manual	21
5	Practice test (past year paper)	23
6	Revision and consolidation	18

Despite having a total of 30 senior students registered in the programme, attendance ranged from 18 to 23 out of 30 for the various sessions. Learners were absent for a variety of reasons. Two of these were clashes with other school programmes and lack of transport to get to the training venue. Those who attended sessions regularly appeared to be keen to learn more about problem-solving strategies and how to use these to solve Olympiad type problems.

Most of the problems discussed during the training sessions involved the use of Polya's four phase plan of problem-solving (Polya, 1973). Three of these problems are discussed here:

Discussed in session 2

A group of children see a herd of cattle in the veld. They count the total number of legs and the total number of ears of the cattle. The difference between these two numbers is 92. How many animals are there in the herd?

Understand the problem: Cattle are seen in the veld. Total number of legs and ears are counted and the difference is 92

Devise a plan: Each animal has 4 legs and 2 ears. Let the number of animals be x. So 4x – 2x = 92

Carry out the plan: 4x – 2x = 92 ⇒2x = 92 ⇒ x = 46. There are 46 animals in the herd

Looking back: We note that 4(46) – 2(46) = 92

Discussed in session 3

A coin and a die are thrown simultaneously. What is the probability of getting a tail and a 6?

Understand the problem: We have a coin and a die and these are thrown simultaneously.

Devise a plan: We know that there are 2 outcomes for the toss of the coin and 6 outcomes for the toss of a die. We have a total of 12 outcomes (6 × 2). To obtain a tail, is one out of two outcomes; to obtain a 6 is one out of six outcomes.

Carry out the plan: One out of two outcomes is written as $\frac{1}{2}$ and one out of six outcomes is $\frac{1}{6}$. We multiple these two fractions $\frac{1}{2} \times \frac{1}{6}$. To get $\frac{1}{12}$

Looking back: We note that if we write down all 12 outcomes then (tail;6) will only appear once only

Discussed in session 5

A positive integer *n* has the property that when the last digit is transferred to the front of the number, the new number so formed is 5 times the old number. Find the smallest value of *n*.

Understand the problem: We have a number with a specific property that when the last digit is transferred to the front of the number, the new number formed is five times the old number. .

Devise a plan: Write n in digit form Nb, where N has m digits and b is a digit from 0, 1; 2; …; 9 then bN = 5 (Nb). That is, 10mb + N = 5(10N +b) so 49N = b (10m -5)

Carry out the plan: If b = 7, we have 7N =10m – 5 and 7 is a factor of 999…5, which is a m digit number. The smallest such number is 99995 = 7.14285, so m = 5, N = 14285 and n = 142857 in this case.

Now if b is not 7, then 49 is a factor of 10m - 5, a number of the form 999…5, a number having m - 1 digits. Long division reveals that there m is at least 6. So 142857 is the smallest number with the property.

Looking back: We check that 5 × 142857 = 714285 which satisfies the given condition in the problem

Data from the questionnaires

Mathematics as a school subject

Learners were asked about their views on Mathematics as a school subject. Learners gave a variety of responses, all positive about the subject. Their actual words are shown here:

> *"You feel that Mathematics is one of the best subjects there is, because it makes our* ***brains work*** *so focus and have to piece things together and bring joy when you can work-out answers"; "Absolutely great yes it is difficult but I love to* ***challenge myself*** *and besides this year my marks have been improving miraculously"; "Mathematics core as a school subject make me feel happiness because it makes me* ***enjoy*** *the Mathematics world"; "Mathematics is* ***fun and enjoyable*** *subject"; "Very* ***interesting*** *work with numbers; "****Interesting*** *but mostly quite chilled"; "Mathematics is a mindset subject and it makes you think and for me it's a* ***challenge*** *I enjoy trying to achieve"; "Is an* ***important*** *subject to be taught in schools and is very enjoyable to learn about" ; "I find it interesting because it helps with* ***other subjects****"; "I feels it's the most* ***important*** *subject"; "Is an exciting subject it helps to be able to* ***solve problems*** *outside of the school" ;"It's fun, I am happy it is a* ***compulsory*** *subject (at my school) , as everything revolves around Mathematics"; "I feel that it is* ***too easy and boring*** *especially as I do AP mathematics which teaches us normal Mathematics concepts for the next year so I know how to do it the next year; it is just repeated"*

Trends from the above comments:

- All learners surveyed had very positive comments about Mathematics as a school subject.
- They found it fun, interesting and enjoyed the challenge presented by the subject
- It assists in solving problems outside of schools and it helps with other subjects
- One learner found it easy and boring as he also did Advanced Programme Mathematics which is aimed at the top learners at his school

School performance in Mathematics

Learners were asked to give qualitative feedback on their school performance in Mathematics. In the main, they responded positively to this question and their actual words are captured here:

> *I do* ***pretty well*** *in school in school mathematics"; "It is* ***relatively average*** *, I would normally aim for 90's but I often achieve 80's , which I am not proud of"; "****Good mostly*** *make silly mistakes"; "I would describe it as having* ***very good*** *this year but I still much more potential and capable of do much better"; "****Good enough*** *I guess because for my recent test I got 76% and 80% for mathematics investigation"; "I* ***enjoy*** *mathematics so I try my best to get good marks in all my tests"; "Great. It's been* ***quite impressive*** *as my marks improves in each task I get"; "****Above average*** *and active in class work"; "My marks have i****mproved;*** *before I was getting average marks"; "It's* ***good*** *I say so myself because of* ***long*** *hours of practice"; "I am* ***well-rounded*** *in the different section of mathematics"; "****Excellent*** *– highest grade mark for few years in a row"*

Trends from the above comments:

- All learners indicated that they were doing very well in mathematics.
- Some who were performing at an average level at one stage were now improving

Learners were also asked to give their marks for their last three Mathematics examinations (December 2017; June 2017 and December 2016). These marks are shown in table 2.

Table 2: Last three exam marks of senior learners

Last three Mathematics examination marks of learners as percentage														
Current grade	**11**	**11**	**11**	**11**	**10**	**10**	**10**	**10**	**10**	**11**	**10**	**10**	**11**	**10**
Dec 2017	60%	56%	96%	75%	83%	60%	73%	97%	99%	75%	82%	90%	98%	93%
June 2017	60%	50%	99%	80%	91%	55%	76%	92%	100%	65%	86%	98%	98%	91%
Dec 2016	70%	50%	97%	70%	85%	65%	71%	91%	91%	80%	80%	96%	99%	92%

Six Learners were in grade 11 and eight were in grade 10. Most of them were performing at 70% and above. Thus, in the main, their previous comment about their school performance in mathematics triangulates with their actual exam marks. These learners appear to have done very well in their mathematics examinations with only one performing at below 60% in all three examinations. These top marks appear to be in line with one of the factors which contributing to the popularity of Mathematics Olympiads at schools, that of learner performance in school mathematics (Govender, 2014).

Participation in Mathematics Olympiads

When asked about why they participated in Mathematics Olympiads, learners gave a number of different responses with all indicating why it was beneficial to do so:

> *"It test **your skills at mathematics** and due to the result it wants you to work others to achieve goals"; "To better my chances of **getting accepted in a university** but in my case in the air force since my dream is to become a pilot" ;"Mathematics Olympiads can give a chance to **challenge** yourself more, learn more and **sharpen** your brain" ;"To **develop** my mathematics because I find it fun" ;"To try out different tasks and improve the way I see mathematics and to **challenge** myself"; "Teaches me skills of **logical thinking** which can help us in our day to day life and provides an **advantage** over other children"; "To **enhance** my Mathematics level and to understand and challenge myself";" To **improve** my mathematics and to try and win the prizes ";"It's the **love** I have for mathematics" ;"To improve my knowledge and the **way of thinking** in mathematics and Mathematics Olympiad are very different to normal Mathematics and it is a really good challenge for yourself to become better"; "Always have since grade 3; its **fun** and always **challenging** and it helps with school Mathematics and **AP Mathematics**"; "**Helps** with normal Mathematics and AP Mathematics questions and concepts; "It challenges you and encourages you to think on **another level** and to look at things from a broader perspective; it is also fun"*

Trends from the above comments:

- Learners participate in Mathematics Olympiads for a variety of reasons
- They loved the challenge posed by Mathematics Olympiads in terms of enhancing one's ability to think logically and become better problem solvers
- Participation in Mathematics Olympiads helps with school mathematics and also boosts their chances of acceptance into university programmes (where mathematics is a requirement)

Table 3, which follows shows the number of years which learners, who completed the questionnaires, have been taking part in Mathematics Olympiads.

Table 3: Years of participation in Mathematics Olympiads/Competitions

Years of participation in Mathematics Olympiads/competitions	
One	5
Two	3
Three	1
Four	2
More than four	3

Trends from table 3:

- Five of the 14 learners indicated that they were participating in Mathematics Olympiads for the first time. This is probably one of the reasons for them joining the programme as they were novices at working with Olympiad- type problems
- Also, five indicated that they have been participating for four years and more. It is probably "second" nature for these learners to work with Olympiad- type problems. Despite these learners being very experienced in Mathematics Olympiads, they still felt the need to attend the training sessions, probably to improve their performance in SAMO round 1.

Reasons for joining the programme

As for some of the previous questions in the survey, the actual words of learners are used when writing their responses on why they joined the training programme.

> *"To help me out at mathematics and **gaining more** knowledge and for my school benefit"; "To **gain advice**, to succeed, get awards, bursary or scholarship to brighten my future"; "On a **challenge** and a **dare**"; "To be **better prepared** for Mathematics"; "The way **they ask questions,** it opens one's mind and keeps me busy"; "I thought it would be a **great opportunity**"; "To **learn better and more advanced** mathematics"; "An opportunity to **improve my marks** in Mathematics Olympiads and improve my knowledge about school mathematics"*

Trends from the above comments:

- They joined the programme to improve their mathematics and gain more knowledge in the subject
- They wanted to become better prepared for the SAMO.
- They wanted to learn more advanced mathematics and to improve their marks in Mathematics Olympiads

Learning in the programme

For this part of the questionnaire learners' comments with regard to what they learnt in the programme have been written with respect to the trends and patterns of coherence arising out of their comments. These are summarised below:

- **How to analyse** and **interpret** problems
- Different **problem-solving techniques**; **diversity** of thinking to solve problems
- Thinking "**outside the box"**
- **Logical** thinking
- How to work with sums; **different ways** of looking at shapes and finding angle or patterns
- Learning from **others**; their views and **perspectives** on Mathematics; how they think, communicate and collaborate

Teaching in the programme

Learners' comments about the teaching in the programme are summarised below:

- The teaching was described as **good to excellent** with **adequate explanations** provided. One learner indicated that he had been coming to the classes since 2015 and was always learning **new things**.
- A number of them, especially those competing in Olympiads for the first time, bemoaned the fact that they were **not allowed to use calculators;** they had to use their ***"brain"*** instead
- A few learners commented that the teaching was **sometimes fast paced** and that the problems **were not always understood.** At the same time there were others who stated that the teaching accommodated **average learners** and also motivated them
- Those with experience in Mathematics Olympiads stated that the teaching covered **various types of questions** which may pop up in round 1

Practice for round 1

Learners' views on whether the training gave them adequate practice for round 1 of SAMO are summarised as follows:

- They were able to solve **relevant questions** and use methods **not previously thought of**. This included the ability to work through **word sums**, **geometry questions and a number of other difficult problems**.
- The examples done in the various sessions and **the practice test** provided **good preparation** for round 1 and not necessarily round 2. One learner who had written round 2 previously indicated that they tend to run out of time

Highlights of the training programme

Learners listed a number of highlights of the training programme. These include:

- They were able to solve mathematics problems using **new** and **innovative** methods. They also enjoyed working in pairs to **share knowledge** and develop **new friendships** with learners from other schools
- They were able to learn the **art of problem solving**; how to **analyse** and **break down** problems.
- Getting **difficult** questions correct was a highlight indicated by most learners
- The **training received** has also **helped** them in school mathematics
- Some indicated that the training programme will ensure that **they did well in the SAMO** and looked forward to being selected to **participate** in the **South African Mathematics Team Competition** as a member of the local team.

Challenges experienced in the programme

Learners also experienced a number of challenges in the programme and these are summarised as follows: :

- **Some indicated that not having sufficient** knowledge in some areas hindered their ability to solve certain problems
- Those participating in Mathematics Olympiads for the first time revealed that it was quite an adjustment of **not being able to use a calculator** and had to **readjust their way of thinking**.
- There were some **arguments when doing problems in groups**, thus, contradicting one of the highlights above
- A few had difficulty with **transpor**t and getting to lessons on time
- The assignments given were **difficult**
- Some had **clashes** with other Saturday activities at their schools

Recommendations to others

All participants surveyed stated that they will recommend participation in the programme to others at their schools and advanced the following reasons for doing so:

- **The programme enlightens** one's way of thinking and working with mathematics
- It enables you to look at school mathematics in **a different way**
- It is a good programme and they would like **others to benefit**

In table the actual results of the learners in round 1 of the South African Mathematics Olympiad are shown. Learners have been given codes SL001; SL002; …; SL030. These codes are used to ensure anonymity of the learners. It must also be noted that learners require a minimum of 50% in round 1 to qualify for round 2. Thus, 50% may be regarded as the "pass" mark.

Table 4 SAMO Round 1 results

Learner code	Round 1 marks
SL001	55
SL002	50
SL003	55
SL004	50
SL005	50
SL006	55
SL007	50
SL008	75
SL009	70
SL010	50
SL011	65
SL012	40
SL013	40
SL014	60
SL015	60
SL016	40
SL017	60
SL018	60
SL019	55
SL020	70
SL021	70
SL022	70
SL023	55
SL024	35
SL025	30
SL026	35
SL027	35
SL028	35
SL029	35

SL030	40

Trends emerging from table 4

- Of the 30 learners in the programme, 20 learners made it to round 2. This is a pass rate of 66,7%.
- Some of the learners did exceptionally well with five getting 70% and above.
- Those who did not make it to round 2 managed to get 6 to 8 questions correct. It is possible that the confidence gained by successfully working through these questions may have a positive impact on their school mathematics.

Findings

The findings of this study are now written with the research questions and sub-questions in mind.

- The Siyanqoba Mathematics Olympiad training programme, at this centre, was a **very intensive support programme** for learners who were registered for round 1 of SAMO. These learners attended classes on Saturdays where they were given tutoring support in **problem-solving** and exposed to a wide range of **Olympiad type questions**. The use of **Polya's four phase problem-solving plan** was embedded in the discussion of the various problems

- The learners who attended this training programme were **top mathematics learners** or learners with **potential in mathematics.** These learners **loved mathematics** and joined the programme to learn **new strategies or methods** to solve problems and assist them in their preparation for round 1 of SAMO

- The research sample of consisted of learners who were **novices** as well as those who were **experienced** in Mathematics Olympiads. Each group had their own reasons for joining the training programme. The experienced learners have been involved in competitions for a number of years and working with Olympiad type questions has become **second nature**. This is in keeping with the Subotnik et al (1996) statement that learners who have been exposed to **challenging mathematics** early in their schooling careers are likely to find the **transition** to more abstract mathematics later on more **easier**

- Learners participated in Mathematics Olympiads for a variety of reasons, one of these being the **love of the challenge** posed by Mathematics Olympiads

- The learners, in the main, found the training very **interesting** and **useful**. They indicated that they learnt a lot and that the training also helped **strengthen** and **enrich** their school mathematics. This is in keeping with Engelbrecht and Mwambakana (2016) about one of the main goals of Mathematics competitions is to enrich the study of mathematics. All learners also indicated that the training had provided them with **adequate preparation** for the first round of SAMO

- Although learners indicated that there were a number of highlights in the programme, the scheduling of the programme on a Saturday morning **competed with other school activitie**s. This had an **impact on their attendance**, which ranged from 60% to 77%. It may have also affected some of their round 1 results
- Despite competing programmes and other challenges, 20 out of 30 learners passed and qualified for the second round of SAMO. This represents a **66,7% success rate**. There also appears to be **some correlation** between the learners' views on the programme and their performance in round 1 of SAMO
- Although the learners who did not make it to round 2 may look at their participation in Mathematics Olympiads as not being successful, the fact that these learners were able to get a number of questions correct may have **boosted their confidence** and possibly impacted **positively on their school mathematics**

Thus, taking the learners' views of the programme and their performance in SAMO round 1, it would be reasonable to respond in the affirmative that the training programme for the learners at this centre was very effective in its preparation of learners for round 1 of SAMO.

Conclusion

Participation in Mathematics Olympiads and competitions forms a crucial part of a child's mathematical development. While some children participate in Mathematics competitions from early as grade 3 or 4, not all schools encourage their learners to take part in Mathematics competitions. As a result some good mathematics learners may proceed to high school and beyond without any participation in such competitions.

The Siyanqoba training programme, as described in this study, was introduced to tap into the vast reservoir of talented mathematics learners in our schools, who through no fault of their own, do not participate in any Mathematics competition. This training programme, as reported earlier, was designed to provide these learners with intensive tutoring in problem-solving and exposure to a wide range of Olympiad type problems in preparation for round 1 of the SAMO. There is no doubt that that the programme was mostly beneficial for the learner participants in this study, with most qualifying for round 2 of SAMO. While those who did not make round 2 may have been disappointed, the knowledge gained from the training would hold them in good stead when they work with problems in their school mathematics.

While training programmes may be effective in the short term, there is a need for more teachers to be involved to ensure the long term sustainability of the Olympiad programme at their schools. These teachers should be trained to coordinate and manage Mathematics Olympiads and competitions at their schools. This should also include tutoring support for their learners.

In these days of high overall pass rates, schools should also embark on strategies to improve quality of passes in subjects such as Mathematics. A school enrichment programme for top learners or learners with potential may help improve the quality of passes.

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Mathematics scaffolding and competitions via mobile devices – reflection on experiences with the TouchTutor Quiz* educational application.

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Keywords: Blended learning, Digital Scaffolding, Information Communication Technology (ICT)-assisted teaching and learning, Mobile learning, E-learning, Language Scaffolding Strategies, Self-Directed Learning

Abstract:

This paper documents the search for digital innovations in the form of mobile applications within the context of emerging pedagogy for addressing critical issues in mathematics teaching and learning, among which are access to learning resources, independent learning, mathematical language competency and motivation. The educational design features, technical testing and experiences with project implementations of an innovative educational application for Android phones are discussed. Developed by the Govan Mbeki Mathematics Development Centre, the TouchTutor Quiz application incorporates key features of mobile learning including ease of use, self-assessment, and access to learning material as well as indigenous language support for mathematics. This application was also extensively tested with implementations of designer mathematics competitions in secondary schools in the Eastern Cape province over the past three years. Both qualitative and quantitative aspects of the impact of these competition projects are discussed. The paper also draws conclusions about the suitability of mobile platforms for learning content, the nature of mathematics competitions best suited for this medium, important application design features of the application and key roles of participants, including teachers, in using it.

**TouchTutor Quiz application was re-launched as the MobiTutorZA™ application in 2020. Since that date, there have been significant changes to the application motivated by on-going action research.*

1. Introduction

Webb and Roberts (2017) argue that, despite the much-documented and on-going crisis in mathematics education in South Africa, there are signs that the sustained effort which has been made to address the crisis is having positive effects in the form of an emerging 'unifying pedagogy' for mathematics education (Olivier, 2017). This pedagogy, in a broad sense, includes creative best-practice in dealing with challenges of teaching development, mathematical identities, technology, linguistic diversity, materials development and research.

The need for such a unifying pedagogy emerges from the context of massive educational challenges in South Africa. The most recent White Paper on Science, Technology and Innovation published by the

Department of Science and Technology (DST, 2018) notes that the South African schooling system is not producing sufficient outputs at the level needed for an advanced Science Technology & Innovation (STI) system and that attending to the problems in English, Mathematics and Science education is a key component of any STI strategy. In turn, an STI strategy is crucial to the achievement of broad goals set in the National Development Plan (NDP) which sets targets for radically improving the quality and quantity of students eligible to study towards mathematics and science based degrees by 2030 as well as for expanding quality and participation rates in the College sector (NDP, 2018).

The Department of Basic Education (DBE) has the responsibility of operationalising macro-level developmental plans for education. Its rationale and strategy for implementation is contained in such documents as the Investigation into the Implementation of Mathematics Science and Technology (MST) (DBE, 2013) and the Revised Strategic Development Plan (DBE, 2016). Important points emerging from these documents include:

- Chronic shortage of mathematics and science teachers and "shortcomings in teacher content knowledge, pedagogy and classroom management" (DBE, 2013, p.11);
- A need for external support partnerships for MST development;
- The key role of Information Communication Technologies (ICTs), e-learning and its derivative, m-learning, in transforming education to enable more learner-centredness, active and exploratory learning, creativity, and analytical and critical thinking skills.

This paper describes and discusses the design, development and implementation of the TouchTutor Quiz application, an innovation in utilizing mobile technology which speaks to a number of key challenges in education outlined above. This application provides scaffolding support for independent learning of CAPS mathematics at any grade level of the Senior Phase and FET school phases. Features include self-assessment, availability of interactive learning and reference material and access to multi-lingual mathematics glossary support. The application also serves as an efficient and widely accessibly vehicle for implementing mathematics competitions and challenges for learners, with elements of gamification, in order to foster problem-solving and critical thinking in mathematics. Recommendations for the use of the application by teachers as a supporting technology for teaching and learning are also made.

The description of the TouchTutor Quiz application is located within a broad consideration of some key concepts in mobile learning (m-learning), in the context of self-directed learning. Cognisance is taken of other recent South African developments in the field and an attempt is made to distil specific contributions and challenges of this development to make recommendations for the further development of the application. An attempt is also made to elucidate its effective implementation on a wider scale as a potentially innovative contribution to a 'unifying pedagogy' for mathematics education (Olivier, 2017) which utilises the undoubted transformative potential of mobile learning in South African schools.

2. Research Context and Questions

2.1 Research Context

The context for the research and development of the TouchTutor Quiz application is formed by the intersection of the following fields of enquiry:

- National educational needs and challenges as outlined in the previous section;
- Changing nature of educational development in the 21st century;

- Self-directed learning (SDL);
- e-learning, its derivatives such as mobile learning (m-learning) and blended learning - the integration of various methods and technologies;
- ICT development and its penetration into South African schools.

The discussion of national educational needs and challenges discussed in the previous section provides the rationale for the current research and development. Innovation which harnesses ICTs to support and improve learning and teaching is urgently needed and current South African policy frameworks make specific reference to the need for partnerships in this area.

Technological innovation must be seen firstly in the broad context of the changing nature of educational development. Gibbs (2013) describes this change as a shift in focus on the classroom to a focus on the learning environment and a shift from teaching to learning. Under this broad rubric of change is included movement towards more self-directed learning (SDL), active, exploratory and problem-based learning, creativity, analytical and critical thinking skills. These skills and competencies resonate with those projected as relevant to the Fourth Industrial Revolution (WEF, 2018).

Self-directed learning (SDL) is a key concept in research on e-learning and its derivatives because these new learning environments imply self-directedness on the part of the learner. Carmargo et al., (2012) distils from the literature the following features of SDL: autonomy, responsiveness, openness, self-questioning, aptitude to determine learning goals and strategy, and the elaboration and enhancement of learning strategies.

While Batholomew's (2016) research cautions that the development of self-directed learning is not primarily linked to technologies and that classroom and teacher characteristics are key variables in SDL, (Carmargo et al., 2012, p. 2) hypothesizes that "technological innovation changes the processes whereby an individual acquires competencies, and that self-directed learning capabilities are required."

E-Learning can broadly be described as the use of ICTs in the teaching and learning process. This is a very broad field which includes on-line courses, learning management systems and assessment systems. It is enabled by ICT innovation and the development of many different technologies and it draws on ideas from Behaviourism, Cognitive Psychology and Artificial Intelligence (Capacho, 2018).

The E-learning White Paper (DBE, 2004) invests e-learning with many of the desired outcomes of a transformed educational system, such as learner-centredness, access to information, effective assessment and overcoming barriers to learning, without citing specific research to show the effectiveness of e-learning to deliver these outcomes. While it is beyond the scope of this paper to explore the evidence for the effectiveness of e-learning, it must be recognized that there has been a fundamental shift in how learning takes place as a result of technological change and that this trend is likely to continue regardless of endorsement by research findings. We therefore proceed from the premise that e-learning is or will become pervasive in South African education and that specific forms of e-learning such as mobile learning (m-learning) should be exploited to take advantage of their potential benefits for learning.
Mobile learning (m-learning) is a form of e-learning which involves the use of mobile devices in the learning process. Rajasingham (2011, p. 7) lists the uses of m-learning as:

- enabling the process and organisation for teaching/learning "on the go";
- allowing for instant communication and collaboration;
- conducting assessments and evaluations and

- providing access to support and knowledge.

Mobility is a key feature of m-learning since it affects the time, place, access to, and context of learning.

Research on the effectiveness of m-learning has yielded some qualified positive outcomes such as a positive correlation between access to m-learning and student achievement (Bartholomew, 2016); the cultivation of ownership of learning (Singh et al., 2011) and positive effects of using gaming to engage learners (Rajasingham, 2011). In addition to measures of effectiveness, what emerges from the research is that the design of the learning experience is key (Singh et al., 2011), that teachers' roles remain important (Bartholomew, 2016) and that the development of a conceptual model for understanding the dynamics of m-learning is needed (Carmargo et al., 2012).

The penetration of ICTs into South African schools varies greatly according to area and socio-economic factors. Despite policy directives and substantial investment in technology in schools, observation in a wide range of schools clearly shows that the general adoption of e-learning in public schools will not become a reality any time soon. In recognition of this reality, Olivier (2017) documents an effective, largely off-line, techno-blended approach for the teaching and learning of mathematics in secondary schools in the Eastern Cape. In contrast to the challenges presented by ICT infrastructure provision and on-line connection in public schools, there is evidence that mobile use is very widespread (Brown in Rajasingham, 2011). Surveys conducted in similar environments by the authors support this finding and the very widespread use of WhatsApp on mobiles for communication shows the extent of mobile use.

O'Hagan (2013) poses the question whether mobile devices can support teaching and learning in South Africa and mentions a range of developments in this general space such as Mxit, Dr Math (Butgereit, 2009), Quizmax, and Siyavula (Lambert, 2019). Other known interventions have included Nokia Mobile Maths and current applications of The Reach Trust such as LevelUP and MathsUp.

There is no doubt that the widespread use of mobile technology currently presents a massive opportunity for facilitating learning improvement. The development of the TouchTutor Quiz application, in the context of mathematics, is a sustained effort to utilise this opportunity.

2.2 Research Questions

The questions which guide the current research are as follows: How can mobile technology best be used in South Africa to:

- promote a culture of independent mathematics learning;
- improve motivation for learning mathematics; and
- provide free access to quality curriculum-aligned learning materials?

3. Methodology

The research methodology used in the study is that of Participatory Action Research (PAR). According to Gravett (2004), action research aims to have both action and research outcomes. It involves processes of repeated experimentation and reflection. Action research is commonly used in the development or improvement of processes or products, particularly where a range of stakeholders have an interest in the outcomes.

PAR is therefore well suited as a methodology for research and development organisations such as the GMMDC, which has initiated multiple cycles of materials and systems development for supporting mathematics teaching and learning in public schools.

Over an extended period during the development of the TouchTutor Quiz application, a succession of cycles of action, evaluation and reflection were employed to develop methods for utilising mobile technology to pursue solutions to the research questions. Both quantitative and qualitative methods were used in gathering feedback on the design, implementation and use of the application. Participation of primary stakeholders (teachers and learners) has been a key element in solving problems, improving designs and developing novel approaches.

Three main cycles of design and development took place. In the first, the prototype of the Android application was developed by adapting an earlier Mxit application by a multi-disciplinary team including mathematicians and educationists from the GMMDC and analyst-programmers from a start-up IT company. Problems solved at this stage included the conceptualisation of objective question types, the design of the content, user and glossary databases, the methods for content representation (which changed from image-based to Latex coding). The Mxit application was discontinued after 2015 and the TouchTutor Quiz application had to be re-developed as a completely independent Android application in 2016. The main development and coding of the application and the web-based back end took place at this initial stage. Testing of the first version of the application was done in-house and then by selected groups of learners and teachers from project schools. Error reports and suggestions for improvement at this stage included basic functionality and content issues. Significant effort went into solving errors which occurred through incomplete development of the synchronisation of on- and off-line modes of use of the application, a key innovative design feature.

The second phase of development was to scale up the content base by developing more question types, generating questions to cover the CAPS mathematics curricula for the GET and FET phases and to solve problems of data representation in the language database. In this phase the application was used for the first time to conduct the mathematics competition for schools, which had previously run on the Mxit online platform. A similar cycle of testing and responding to feedback occurred at this stage with the focus more intensely on content issues. Content was successfully extended to cover the CAPS mathematics curriculum for Grades 8-12 and the application reached a state of functional stability after this cycle.

In the third phase, development focused on strategies for gamification, reward and promotion mechanisms and the inclusion of a more flexible and extensive set of formats and filters for delivering learning and reference material such as past papers, notes and learning reference documents. Stable versions of the application were used in the competition and the number of functional errors were minimal. More than 1200 learners and approximately 100 teachers from more than 50 schools were again involved in the testing and use of new features of the application. School contexts ranged from well-resourced urban schools to under-resourced rural schools.

Methods used in all phases of design and development included specification documents and flow charts; an on-line ticketing system for bugs; system and user generated flags for error conditions and feedback; periodic meetings of the inter-disciplinary project team and the use of testing staff who systematically worked through subject content. Feedback was facilitated by using email, WhatsApp and Facebook.

The PAR methodology employed has been significant in developing the application and its associated curriculum aligned content to a point of relative stability and completeness. The iterative nature of the methodology, the number and diversity of users involved and an openness to feedback have been essential in making this a dynamic development. To some extent the development processes have embodied features of the Living Labs methodology proposed by (Carmargo et al., 2012).

4. Outcomes and Results

The outcome of the design and development is a relatively mature Android mobile application which implements multiple objective question types with immediate assessment, scoring and feedback. Questions are grouped in syllabus-aligned topic-based mathematics tests which are either open or assigned to a group within a specified time window. User history is maintained through a table of test results and rankings are done through earned tokens and leader boards. The application makes available a customisable range of learning and reference material of various technical formats, including interactive multi-language support.

4.1 Evolution of the TouchTutor Quiz model

The TouchTutor Quiz application was developed by the GMMDC as an integral component of the centre's hybrid offline-online Techno-blended model for supporting mathematics and physical sciences teaching and learning in secondary schools. The framework for this model is shown in Figure 1 below.

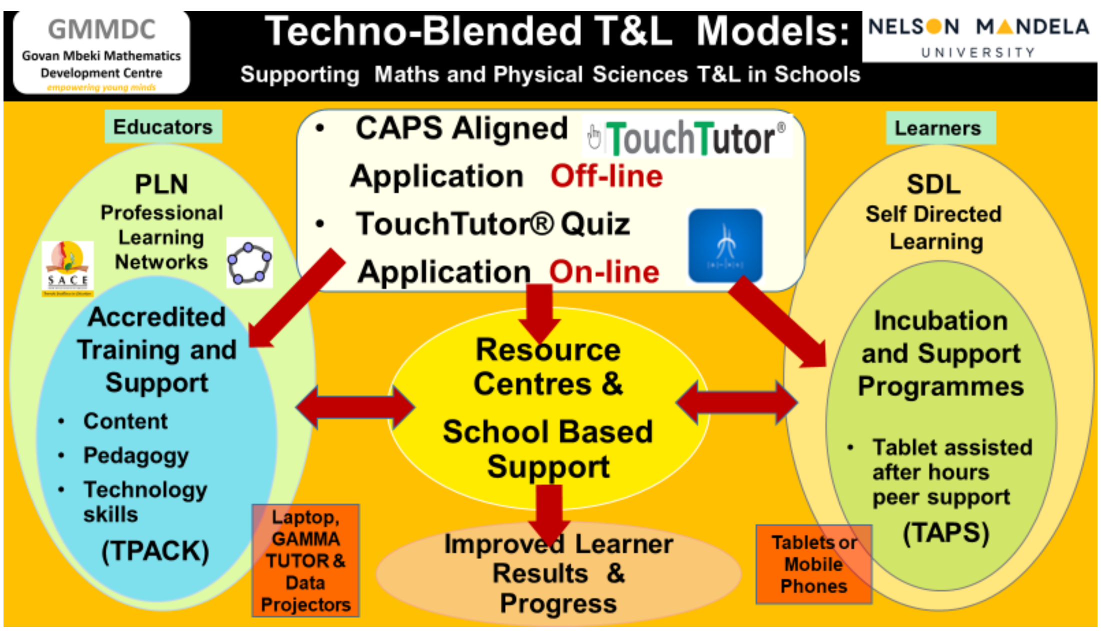

Figure 1: The Techno-blended Model of the GMMDC

The model is at the heart of the centre's theory of action for change which itself has developed through PAR over more than a decade. Key features of the model are the inclusion of learner incubation, professional development and support of teachers and resource development. The innovative use and synchronisation of on- and off-line technologies and a strong focus on improved learner results and pedagogical development which includes promotion of creative cross-curricula approaches such as Science Technology Engineering Arts Mathematics (STEAM) education are also central to the Techno-blended approach.

Model Evolution

	← 2011	Digital Divide	2013	2014	2015; 2016	Android Development	2017	2018	2019
	UPE/NMMU Mathematics Competition		MathsMxit Competition	TouchTutor Competition	TouchTutor Competition		TouchTutor Competition & open tests	Competitions, challenges, language and Curriculum support	
Reach	Provincial		Provincial	National 84% E.Cape 16% other	National		E. Cape pilot	East Cape & FS	National
Subjects	Mathematics		Maths	Maths & Science	Maths & Science		Maths	Maths & Science	multiple
Participants	Larger numbers		Maths: 592	Maths :577 Science: 186	↑		1200	2500 & teachers	Target 5000
Medium	Paper-based		Mxit - phones	Mxit – phones and other mobiles			Android App on mobiles		
Registration	Through schools		Teachers & schools, then Mxit	Individual, automated on Mxit			Individual, automated on TTQ app		

Figure 2: Evolution of the TouchTutor Quiz Model

Figure 2 shows the chronological development of the TouchTutor Quiz and the recent history of the TouchTutor Quiz Mathematics Competition. It is evident that changing technologies and applications have influenced how the competition has been offered and the extent of participation during a period of rapid technological innovation (Collett & Weisswange, 2014). It can be argued that the survival of the competition through cycles of technological change is a significant achievement of the GMMDC. By 2012 the financial, logistical and communication constraints of running a paper-based competition was threatening its continuation. Many of these constraints were solved by implementing the competition using mobile technology, thus enabling the continuation of the competition project.

4.2 The TouchTutor Quiz system

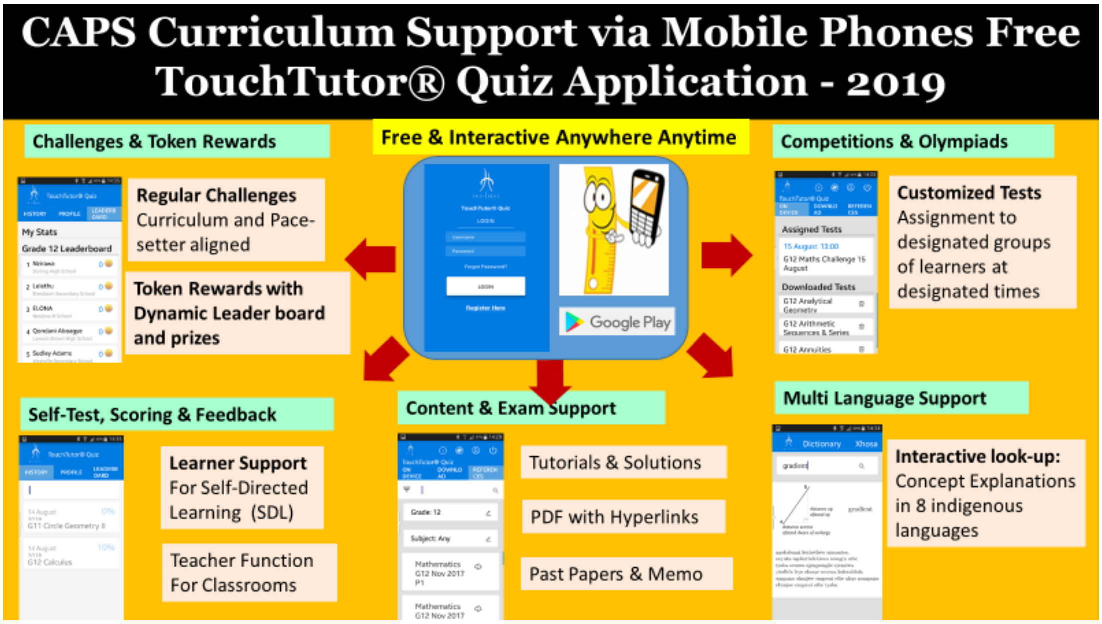

Figure 3: The TouchTutor Quiz Application in 2019

Figure 3 shows an overview of the main components and the intended uses of the TouchTutor Quiz system. Special features are described in more detail below.

4.3 System Characteristics and Statistics

Developed by the GMMDC in collaboration with IT company Avocado Chocolate, the TouchTutor Quiz system (v.1.3.9) is a free Android application (suitable for versions 4.3 to 8) which is available on Google Playstore, published by Ever Africa, or can be custom loaded on a mobile device. The application size is approximately 27 Mb. Tests typically require minimal data to download and learning material vary in size depending on their extent. The system is hosted within an elastic beanstalk environment which dynamically allocates resources according to load. Currently the application system implements 6 question types. The mathematics database contains 2263 questions, 256 open tests, 98 assigned tests and over 1750 registered users. All functionalities of the TouchTutor Quiz application can be utilized off-line in respect of any learning and support materials that were downloaded.

4.4 Special Features

4.4.1 Learning materials

The system supports the download of learning material in various formats such as PDF and E-pub. Inclusion of videos is planned for the near future. Materials currently available on the system include extensive reference material for mathematics and physical sciences which includes standard and extended formula sheets, complete lists of Euclidean Geometry theorems, notation, and data sheets. The reference material is supplemented by topic notes. In addition, past national and provincial mathematics examination papers and memos for all grades (8-12) can be accessed. Although the system would support the hosting of a comprehensive set of learning materials, the intention at this stage is to restrict learning material to a sufficient set of quick references, notes and past papers with due consideration to data demand for downloading. Full coverage of the CAPS curriculum is available through the off-line TouchTutor® application of the GMMDC which also houses a wide range of mathematics and physical sciences video lesson series and related digital support materials.

4.4.2 Language support

Jantjies and Joy (2015) have documented the need for mobile resources to support mathematics learners who employ code-switching in a multilingual learning environment.

The TouchTutor Quiz application includes a multilingual mathematics glossary which gives users access to language support on demand at any point in the use of the application. The languages supported are English, Afrikaans, IsiXhosa, IsiZulu, Sesotho, Sesotho sa Leboa, Setswana and Tshivenda. Users can access explanations of mathematics concepts that are presented on demand with English side by side with any other chosen indigenous language. The innovative provision of language support in this way could be an important scaffolding support of for users learning mathematics is their second or third language. This feature was possible by collaboration between GMMDC and Ithuta Books (Fricke & Meyer, 2014) through a licencing agreement and the technical conversion and integration into the application of the separate glossaries using Latex® within a customised database.

4.4.3 Learning Management

Use of the application as a self-assessment tool for CAPS mathematics and for scaffolding support by using references, notes, past papers and language support relies, to a large extent, on the self-directed learning skills of the user.

Access to assessments and learning materials is organised hierarchically in grades by the use of filters and the onus is on the user to find the material they want to study. The system keeps a complete list of test results listed chronologically. The memorandum for each test taken is available on demand in the wake of the completion of a test.

Performance details for each learner, or for a particular assessment are available to system users through the administrative portal of the application and this facility will soon be available for teachers. This allows for valuable profiling of the mathematical competence of individual users or groups.

4.4.4 Gamification

Gamification in the TouchTutor Quiz application is currently restricted to the earning of tokens for assigned tests. Tokens are accumulated and users are ranked accordingly on Grade leader boards. Performances on Monthly Maths Challenges and all competitions earn tokens Prizes are awarded on a regular basis for top positions on each leader board and for levels of participation. This functionality of the application is currently in a pilot phase and holds great promise to be used with customized target groups of expanded to support mathematics learning at scale in South Africa.

5. Discussion

The major outcome of this research and development study is the implementation of a stable application with many desired features as informed by the key education challenges in the 21st century. A substantial proof of concept has been achieved in respect of using a customized Android application to support self-directed learning of CAPS mathematics via mobile phones.

Each of the research questions has been answered affirmatively and is supported by positive feedback from learners and teachers who have used the application for curriculum support or for competitions.

As indicated in Figure 2 above, the development of the model has enabled a growth in the user base of learners and teachers. Over the period 2014 to 2018 user numbers grew from approximately 600 to over 2500. Over the same period the range of uses of the application diversified from a single function of the maths competition to multifaceted self-assessments, access to learning materials and language support. PAR has proved an effective methodology in this research and development context.

Positive comments from learners tend to focus on problem solving improvement, the learning process and access to learning materials:

> *" The APP has been very much productive ; has helped me to improve my problem solving skills."*
>
> *"it encourages us to study and there are breakdowns [solutions] when you got an incorrect answer."*
>
> *"It is a good reference tool and study kit and has helped me improve my marks."*

Difficulties experienced by learners who have used the application include lack of data for access, some technical issues with the hybrid on- and off-line nature of the app and challenges experienced with the difficulty level of competition questions.

The innovation of the TouchTutor Quiz application lies in the utilisation of digital technology to support key elements of new learning paradigms such as self-directed learning, gamification (competitions), interactivity and flexibility within a context and medium which resonates with the expectations of today's Generation Z learners (Diego, 2020). At the same time the application capitalizes on the power of technology to provide structure and tracking as well as to accumulate valuable data on learning behaviour for profiling and research purposes. The TouchTutor Quiz project is an example of the powerful role that institutions of Higher Education can play in trans-disciplinary innovation for engagement and the good of society.

Unique elements of the development project include interactive multi-language support and comprehensive curriculum aligned self-assessment coverage of the CAPS mathematics curriculum in a mobile learning environment. No other known applications for mobile phones in South Africa have these features integrated with content support in one application.

5.1 Challenges for further innovation and research

Pedagogical

Ongoing interrogation of the educational design is necessary to further develop the application in ways which consider dimensions of self-directed learning. Additional features of this nature need to be integrated with functional requirements for an efficient assessment system and a content delivery platform. A key area for improvement could be to enable learners more freedom to choose customized content within assessments, to track their choices and engagement profiles. Another improvement could be to provide clear graphic interpretations of learning progress as part of the management of learner profiles. Extension of teacher app functions to allow more freedom to set and schedule customized tests for classrooms to augment pedagogical practice also holds great promise.

Technical

Implementation of additional media formats such as e-pub and video are currently being explored.

Expansion of the portal to open up learning management and reporting facilities to teachers and facilitators is in the testing stage and will soon be available.

Curriculum

There are opportunities to extend TouchTutor Quiz content to Technical and Vocational Education and Training (TVET) College mathematics curricula and to other subjects in the FET and GET bands of school education. Partnerships will be key in achieving such curriculum extensions.

Social Communication

Linkage with social media systems for promotion and building of a learning community and community of practice of educators has recently been implemented and will need to be monitored and further developed.

Gamification

Further aspects of gamification have been conceptualised and are being considered for implementation. These include the customisation of a character for each user, awarding badges and challenges between users or groups of users.

5.2 Reflection on research questions

In summary, we argue that the TouchTutor Quiz application is an example of the effective use of mobile technology in South African education and that its features are well suited to promoting a culture of independent mathematics learning. Its gamification aspects and learning management features are designed to improve motivation for learning through participation and immediate feedback, and the application provides free access to quality curriculum-aligned learning materials.

6. Conclusions and Recommendations

6.1 Conclusions

Specific conclusions emerging from the experience of developing and implementing the TouchTutor Quiz application include the following:

- Mobile technology holds great promise to provide an effective platform for encouraging independent mathematics learning. TouchTutor Quiz is an example of an effective m-learning application in this context which has been sustained for a significant period and has survived many technical platform changes. Mobile technology offers significant advantages over other media in the efficient and cost-effective implementation of mathematics competitions (at scale or otherwise) in schools. The TouchTutor Quiz competition project has enabled NMU to continue a long tradition of mathematics school competitions where traditional print and post systems experienced terminal roadblocks.
- A broad-based, curriculum-aligned approach to mathematical content support via mobile phones encourages wider learner participation, especially in disadvantaged school contexts. Cell-phone ownership and network penetration in disadvantaged areas may have reached a tipping point which will facilitate wide and viable implementation. This holds promise for improvement in access to and quality of mathematics learning in schools.
- Gamification is an important motivational aspect of application design in attracting wider participation amongst school learners as it is one of the key expectations of the current generation of learners. TouchTutor Quiz has implemented a modest form of gamification through tokens and leader boards which is encouraging participation.
- Teacher involvement in encouraging learner participation in mathematics challenges and competitions is a key enabling factor for sustainable educational scaffolding at scale. GMMDC utilises South African Council of Educators (SACE) accredited professional development programmes for in-service mathematics teachers as an opportunity to promote m-learning (with TouchTutor Quiz) using a TPACK framework (Koehler & Mishra, 2005).
- Access to interactive multi-lingual support within the mobile phone application enables engagement with language challenges synchronously in real time. This aspect of the application has been enthusiastically received by users.
- This application innovatively integrates of a number of key educational support functionalities (curriculum support, assessment, language support and gamification) in one interactive digital learning environment.
- The broader application of the TouchTutor Quiz system in other educational sectors and for a range of subjects is now technically possible.

6.2 Recommendations

For the application to reach its potential for supporting and improving mathematical learning, further research and development is needed in the following areas:

- Use of social media platforms to form a learning community around the application;
- Further development of the options for content choice and management so that individual customisation of the learning experience is enabled;
- Investigation of partnerships and mechanisms for improving network access. These may involve targeted sponsorship, zero rating, and partnerships with service providers among others;
- More general logging and analysis of user selection of content and participation patterns for challenges and competitions, as well as collection of qualitative reflective data which will guide future development;
- Targeted research to track the take-up of gamification elements of the application and gathering of user perceptions and behaviours around this;

- Setting up protocols for investigating the use of language support facilities as a means of understanding user needs in this area;
- Effective networks for the promotion of the app to teachers and schools.

In conclusion, this paper has sought to document and present an innovative research and development project in mobile learning which contributes to a ‘unifying pedagogy’ for mathematics education in South Africa. The project has potential for extension and improvement through further action research with stakeholders and could assist South African schools in rising to the challenges of educational renewal and the effective use of technology (Nagel, 2013).

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Understanding Self-Regulated Learning and Self-Efficacy in Project-Based activities: Case Studies of selected Eskom Expo for Young Scientists Alumni

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Abstract

Initiatives to improve schooling in South Africa and address the skills shortages have mostly focused on performances in exit examinations with little attention given to the role of human agency in contributing to improved educational outcomes. Learners regulating their own learning and its effect on self-efficacy beliefs are examples of these less overt contributors to educational performance. Project-Based Learning performances were found to be dependent on learners' ability to self-regulate. The aim of this small-scale exploratory study was to understand the self-regulated learning strategies of a sample of Expo alumni who have completed project-based tasks. The participants were ten alumni who participated in at least two levels at Expo from 2016 to 2018, have received at least one achievement award, and were studying in a science, technology, engineering or mathematics field. It was found that the participants' self-efficacy beliefs were strongly related to their inquiry skill sets rather than their content knowledge. Regarding self-regulation, the participants' received no support from teachers and schools during the *Problem Identification Phase*, which was found to be critical for success in project-based learning. Other areas of inadequate regulation included metacognition and reflection. Recommendations made include structured support, especially at the initial phase; development of inquiry skills; activities for self-reflection; and role modelling.

Introduction

Reddy and Juan (2015) reported that a mere 18% of grade 12 learners met the criteria for tertiary studies in science, mathematics, engineering, medicine and commerce fields. They added that considering high attrition rates, the far fewer graduates produced would not be able to meet the requirements of South Africa's skills shortage, as identified by the *National Development Plan*. While the South African Grade 9 learners' performance in the 2019 Trends in International Mathematics and Science Study (TIMSS) showed marginal improvement, a decrease in the rate of improvement was of concern (Reddy, V., Lolita, W., Juan, A., Arends, F., Harvey, J., Hannan, S., Namone, C., Sekhejane, P. & Zulu, N., 2019). Reporting on TIMSS 2019 results, these authors once again stressed the importance of high-skilled tertiary education graduates for a changing South African economy. Reddy et al. (2019) claimed that, "The increased proportion of Grade 9 learners demonstrating improved abilities in mathematics and science could increase the mathematics and science pipeline to the exit level matriculation examination, and further into tertiary studies" (p. 20). Equipped with the relevant skills, such an output will contribute to the much-needed skilled workforce that is needed to navigate the 21st Century. The many well-meaning initiatives to improve schooling in South Africa have mostly focused on curriculum design and implementation, teacher training, and resource allocation. Little attention is given to the role of human agency in contributing to improved educational outcomes. An example of this often overlooked area is self-regulated learning where learners take responsibility for their own learning. A pedagogy that has shown to yield successful outcomes when one's learning is self-regulated, is Project-Based Learning (PBL) (Blumenfeld, P., Kempler, T. & Krajcik, J., 2006).

Project-Based Learning is a learner-centred, inquiry-based approach that supports the development of essential skills such as complex problem solving, critical thinking, analysing and evaluating information, working cooperatively and communicating effectively (English & Kitsantas, 2013). Inquiry has been described as both a means and an end. Inquiry as a "means" refers to inquiry *in* science, which is the instructional approach that helps learners understand science content (Abd-El-Khalick, F., Boujaoude, S., Duschl, R., Lederman, N. G., Mamlok-Naaman, R., Hofstein, A., Niaz, M., Treagust, D. & Tuan, H., 2004). Inquiry as "ends" is inquiry *about* science. Learners do inquiry in the context of science through investigations where they learn about the nature of science, gain scientific knowledge, and acquire inquiry skills (Bell, S., 2010). PBL has five key features: a driving question or problem; an inquiry process that explores this driving question or problem; collaborative activities; use of technologies; and developing answers, products or solutions (Blumenfeld, P. et al., 2006). Unlike projects, PBL is driven by an inquiry question, places the learner in authentic real-life situations, requires them to be engaged over extended periods, and promotes inter-disciplinary learning. Blumenfeld (1991) stated that over a quarter of a century's research and development on PBL have suggested that curricular design and practice requires a focus on curriculum content as well as the psychological factors associated with learning, for it to be meaningful.

Eskom Expo for Young Scientists (Expo) is a non-profit organisation primarily concerned with developing inquiry and research skills of school-going learners through PBL, in line with the South African Curriculum and Assessment Policy (Department of Basic Education, 2011). Expo focuses on research in the broad areas of scientific investigations, engineering, computer sciences, mathematics, theoretical studies, and the social sciences. Expo focuses on development and training in PBL and reaches learners in 35 regions across all nine provinces. In these 35 regions, volunteers train and develop learners, teachers and judges on PBL. The 35 regions host school; district; and regional science fairs were learners drive their own research independently and are given opportunities to present their project work individually or in teams to judges. Selected learners may proceed to compete in international science fairs. Expo works strategically to increase its reach to a range of contexts. Hence, it is important to understand PBL in the South African context so initiatives are crafted for learners of diverse groupings, appropriate resources are developed, and meaningful training are provided. From its inception in 1980, several Expo participants have made significant contributions to science and engineering research. A wealth of knowledge and experience, including PBL, lies with the thousands of Expo alumni, many of whom have returned to inspire and support future young scientists.

PBL, which places the responsibility on learners to access information, achieve goals, manage their resources and monitor progress, is dependent on the learners' Self-Regulated Learning skills (SRL) (Paris, S. & Paris, A., 2001, Sungur, S. & Tekkaya, C., 2006). SRL refers to the degree to which learners metacognitively, motivationally and behaviourally participate in the learning process (Zimmerman, B., 2002). Zimmerman (2002), defined SRL as the process learners use to activate and sustain their thoughts, behaviours and emotions to reach their goals. Self-regulated learners who can initiate their learning, set goals, choose appropriate learning strategies, monitor and evaluate their progress, are more likely to be successful (Zimmerman, B., 2002, Hmelo-Silver, C., 2004). Studies showed that SRL is a requirement for successful inquiry-based learning (English, M. & Kitsantas, A., 2013). Augustiani, Cahyad, and Musa (2016) found that there was a strong relationship between the use of SRL strategies and students' academic achievement. Zimmerman, et al. (1992) showed that SRL had a causal relationship with perceived self-efficacy beliefs. SRL was found to influence career choices through regulating career-related behaviours and educational performances (Tseng, K., 2013, Bandura, A., Barbaranelli, C., Capara, C. & Pastorelli, C., 2001). It was found that first-year engineering students' experiences were influenced by their self-efficacy beliefs (Hutchison-Green, M., Follman, D. & Bodner, G., 2008). Britner & Pajares (2006) found that science school learners' successful experiences significantly predicted their science self-efficacy and in a development study of self-efficacy, Pajares & Valiante (2002) found that learners' confidence decreased from primary to high school. In the South African context, there is a gap in our understanding on whether or how successful Expo learners self-regulated their learning and how their self-efficacy beliefs influenced this. The aim of this small-scale exploratory study was to understand the self-regulated learning strategies of a sample of Expo alumni.

Theoretical Framework

Project-Based Learning (PBL) is premised on four theories of learning: active construction, situated learning, social interaction, and cognitive tools (Blumenfeld, P. et al., 2006). Active construction occurs when a learner actively constructs meaning to develop understanding. Situated learning refers to authentic learning situated in real world contexts while social interaction refers to learning from social interactions, and cognitive tools describe the tools of learning. PBL require self-regulated learners who are self-efficacious about their ability to master learning tasks (Bandura, A., 1991, Pintrich, P. & De Groot, E., 1990). In Pintrich's (2002) model of SRL, learning is organised into four phases: *forethought phase* (planning), *performance phase* (control and monitoring), and the *self-evaluation phase* (reflection). According to Zimmerman (2002), planning, monitoring and control involve metacognition, which is the awareness, knowledge, and control of cognition, that is, how and why learners choose particular strategies.

English & Kitsanta's (English, M. & Kitsantas, A., 2013) model of the relationship between PBL and SRL illustrates how the gradual transition to SRL takes place in PBL. As the guidance from the teacher decreases, the learners' SRL skills increase. The first phase of PBL is the *project or problem initiation* where the learner formulates and understands the driving question. This phase is critical for the success of the task, requires increased guidance from the teacher, and relates to the *forethought phase* of SRL where the learner analyses the task, sets goals, and plans. The SRL processes that support PBL are identifying resources, activating prior knowledge and motivation. In Phase 2, the *guided inquiry and product or solution creation* phase, learners gather data, make meaning, reflect and test-retest or design-redesign and make the necessary adjustments (English, M. & Kitsantas, A., 2013). This phase corresponds to the *performance or control* phase of SRL where learners engage in complex learning tasks and construct their own knowledge. The SRL processes include self-observation, monitoring progress, reflecting and revising ideas. During Phase 3 of PBL, *project conclusion*, the learners reflect on their overall learning and share their findings and this corresponds to the SRL processes of *self-evaluation*.

Self-efficacy is one's belief in one's capabilities to learn or to perform tasks effectively and is theorised to influence performances through three sub-functions: self-monitoring of one's activities; adoption of goals to motivate and strategies for realising the goals; and through social supports (Bandura, A. et al., 2001). Hence, people must develop skills to regulate the motivational, affective and social aspects of their cognition. Efficacious people set challenging goals and believe that they can accomplish them. Bandura proposed that four factors influence the perception of efficacy. *Mastery Experiences* refer to having accomplished something successfully and is the most effective way to boost self-efficacy. *Vicarious Experiences* refer to learning from other's successes or modelling after them. *Social Persuasion* is the encouragement and support from others and *Physiological States* refer to the stress of thinking about new behaviour.

Research Question 1: What were the participants' sources of self-efficacy beliefs when completing the Expo project-based tasks completed?
Research Question 2: Which self-regulated learning strategies did the participants use when completing the Expo project-based tasks?

Methodology

Design and Procedures

Hutchison-Green et al. (2008) stated that efficacy theorists such as Albert Bandura and Frank Pajares recommended a discovery-orientated, qualitative approach to best understand participants' self-efficacy beliefs. They added that qualitative approaches allow for in-depth analyses of the experiences of few participants. Zarouk, Oliviera, Peres, and Khaldi (2018) maintain that qualitative approaches are ideal for in-depth studies of PBL that seek to explore phenomena. Exploratory studies are ideal for studying phenomena where little research has been done and there is a need to gather more information (Cohen, L., Manion, L. & Morrison, K., 2005). In this study, participants' experiences of PBL, their use of self-regulatory skills and their perceived self-efficacy beliefs were explored. Studies involving reflection are useful because participants can report on their experiences in hindsight as if they were removed from that instant in their past. However, reflective studies rely on the memory of participants to describe their experiences and this may include bias (Zarouk, M. Y. et al., 2018). In this study, each of the participants' reflections on their experiences of PBL was viewed as unique with no intention of making generalisations but areas of commonalities were noted.

The Participants

Biographical data, as well as information on Expo participation, schooling, and current studies were collected from twenty-two Expo alumni who participated in regional and national level science fairs from 2014 to 2018. The criteria used in the purposive sampling were alumni who participated in Expo from 2016 to 2018 (most recent 3 years) in at least two science fair levels (regional and national), with at least one achievement award (medal or certificate), and was studying in a science, technology, engineering, or mathematics field in 2019. The sample had to include both male and female participants who completed research projects centred around a problem or driving question, and used an investigative method, engineering design, theoretical or social studies inquiry method. In addition, to include a range of contexts, participants from each of the nine provinces and quintile schools were represented in the sample. The quintile ranking system is used by the Department of Education to categorise schools into five groups for the purposes of allocating resources. Schools classified as quintile one are defined as poor while quintile five schools are least poor. Ten participants from the initial group of twenty-two alumni fulfilled the afore-mentioned criteria. There were several criteria to fulfil and this resulted in the small sample in this study. One alumnus was selected from each of the nine provinces with the exception of Gauteng where two alumni met the criteria. The two participants from Gauteng each attended a private and a quintile five school. The participant from the Western Cape attended a private school, while the participants from Northern Cape, KwaZulu-Natal and Eastern Cape attended urban quintile five schools. The participant from the Free State and the North West provinces attended quintile four schools from townships and the quintile one schools were represented by participants from Mpumalanga and Limpopo provinces. The current (2019) ages of the ten alumni ranged from 19 to 21 years with five being female and five male. Descriptions of the ten participants are provided in Appendix A.

The Instruments

The questionnaire and the semi-structured interview schedule were piloted with three Expo alumni (exclusive of the ten participants) from Gauteng province because of the convenience of access. The initial interview schedule consisted of 20 with 110 items and this was reduced to 10 questions after the pilot study. In the pilot study, the questions were checked for relevance, appropriateness, bias, ambiguity, duplications and validity. The participants had to indicate which questions they did not understand or know how to answer. Bandura's (2006) "Guide for Constructing Self-Efficacy Scales" was used to guide the construction of the items on the self-efficacy questionnaire and ensuring content validity. The 110 items of the initial questionnaire were reduced to 60 items after the pilot study.

To answer the first research question on the sources of the participants' self-efficacy beliefs, the participants completed the Self-Efficacy Questionnaire (Appendix B). The sixty items of the questionnaire were divided into four sets: Mastery Experiences, Social Persuasion, Somatic Experiences and Vicarious Experiences. Using a 5-point Likert Scale, the participants' self-efficacy was established through sub-sets as follows: Mastery (organisational skills, knowledge gained, understanding of research, skills gained and communication skills); Social Persuasion (learners, teachers/school, judges at Expo, Expo as an institution, family); Somatic Experiences (fear, embarrassed, confused, anxiety, confidence); and Vicarious Experiences (learners at school, learners at Expo, Expo alumni, scientists). Each of the afore-mentioned Likert-type subsets consisted of three questions. The participants scored the items as follows: 1 = Strongly Disagree; 2 = Disagree; 3 = Undecided; 4 = Agree; and 5 = Strongly Agree. Some of the items included reverse statements. To answer the second research question on the self-regulated learning strategies used, the participants were interviewed using the semi-structured Interview Schedule (Appendix C). The interviews explored whether or how the participants used SRL strategies when completing their Expo project-based tasks. The three phases of the SRL interview were *Forethought*, *Performance*, and *Reflection*. The *Forethought* section gathered data on the context of the project work, the value they assigned to the project work tasks, goal setting, time management, and planning of the task. The *Performance* section of the interview dealt with the assistance received when carrying out the task, perceptions of difficulty, organisation skills, access to resources, and what informed choices made. The final section of the interview was concerned with the *Reflection* activities after the project work was completed.

Data Collected

This exploratory study collected and analysed descriptive data from the questionnaires using quantitative statistical analyses. The variables from the questionnaire represented ordinal data and had to be analysed using nonparametric statistical tests (Sullivan, G. & Anthony, R., 2013). Each Likert Scale item was prepared for statistical analysis by combining the scores from the three items from the Likert subset, into a single composite score/variable by establishing the median (Appendix D). According to Raiphea (2015) a variable is an image, perception, or concept that can be measured. The Likert Scale scores were analysed to determine the mean, mode, range, and frequency. The mean, standard deviation of the mean and variances of the scores were not calculated since for ordinal data of Likert Scales, establishing the mean is not only unnecessary but cannot be used to describe the data. The data were then represented in tables generated from the *SPSS* software used (Appendix E). Since the study collected descriptive ordinal data, no correlations or comparisons were required and hence no further analyses were done. In addition, due to the small sample size *(n=10)*, it was not necessary to calculate the internal consistency and reliability of the items on the questionnaire using the Cronbach's Alpha test. Data from the interviews were analysed qualitatively using *NVivo* software to generate themes, using pre-determined categories from the literature.

Results and Analyses

Self-Efficacy Beliefs

Using pre-determined categories from the literature (Mastery Experiences, Vicarious Experiences, Social Persuasion and Somatic Experiences) in a questionnaire, the participants' self-efficacy beliefs in the context of the Expo project-based learning tasks were analysed.

Mastery Experiences

For the accomplishment of Mastery Experiences, the subscales of organisational experiences, knowledge gained, learning how to do research, skills gained, and communication were explored (Appendix E). Six out of the participants were undecided about gaining knowledge from their tasks. Most participants agreed that they required organisational, research, and inquiry skills for the tasks (Table 1).

Table 1 Frequency Scores: Mastery Experiences from the Expo project-based tasks

	Organisational Skills	Knowledge	Research Skills	Inquiry Skills	Communication
1 Strongly Disagree					
2 Disagree					
3 Undecided		6	1		4
4 Agree	4	2	5	7	4
5 Strongly Agree	6	2	4	3	2

Social Persuasion

For the sources of Social Persuasion, the learners at school, teachers/school, judges, Expo as an institution and the family were explored (Appendix E). For the subscales of both the *teachers* and *judges at Expo*, strongly disagree was most selected (Table 2). The range for the subscale *learners* had the largest range of 3 with a minimum of 2 (disagree) and a maximum of 5 (agree).

Table 2 Frequency Scores: Social Persuasion Experiences from the Expo project-based tasks

	Learners	Teachers / School	Judges	Expo	Family
1 Strongly Disagree					
2 Disagree		4	4		
3 Undecided	3	1	3		
4 Agree	5	4	3	3	4
5 Strongly Agree	2	1		7	6

Somatic Experiences

For Somatic Experiences, the constructs of fear, embarrassment, confusion, anxiety, and confidence were explored (Table 3). The median for fear was 2 (disagree) and embarrassment was 1 (strongly disagree), while confusion, anxiety and confidence were all 4 (agree).

Table 3 Frequency Scores: Social Persuasion Experiences from the Expo project-based tasks

	Fear	Embarrassment	Confusion	Anxiety	Confidence
1 Strongly Disagree	3	8	1		
2 Disagree	4	2	2	1	
3 Undecided	3		1	2	1
4 Agree			6	5	4
5 Strongly Agree				2	5

Vicarious Experiences

To establish who influenced the participants the most, the participants scored on the following items: learners at school, learners at Expo, Expo alumni, and scientists (Appendix E). The median score for alumni and scientists were both 1 (strongly disagree). Most participants strongly disagreed with the Vicarious Experiences related to learners from school, alumni, and scientists (Table 4).

Table 4 Frequency Scores: Vicarious Experiences related to the Expo project-based tasks

	Learners at School	Learners at Expo	Expo Alumni	Family	Scientists
1 Strongly Disagree	4	2	9		6
2 Disagree	2	4	1		1
3 Undecided				3	1
4 Agree	2	4		2	2
5 Strongly Agree	2			5	

Self-Regulated Learning Strategies (SRL)

From the interviews, the SRL strategies that were used most frequently for the Project-Based Learning activities were identified as organising, time on task, and seeking social assistance from structures outside school Appendix C). All ten participants identified the first Phase of PBL *(Forethought)* as the most difficult and confusing, and sought social assistance from outside of school. Self-evaluation was mentioned least frequently during the interviews (Table 5).

Table 5 Self-Regulated Learning Strategies identified per participant

Participant	Self-Regulated Learning Strategies				
	Organising	Time on Task	Self-Evaluation	Social Assistance outside school	Difficulty: PBL Phase 1
1	x	x		X	X
2	x	x		X	X
3	x	x	x	X	X
4	x			X	X
5	x			X	X
6	x		x	X	X
7	x	x		X	X
8	x	x		X	X
9				X	X
10				X	X

Discussion

This study did not seek to generalise based on the findings, neither was the intention to compare results statistically. The statistical analyses were used for simple tasks such as counting, median, and frequency. Descriptive analyses were primary used in this qualitative study. Bandura defines self-efficacy as “people’s beliefs about their capabilities to produce designated levels of performance that exercise influence over events that affect their lives” (Bandura, A., 1994). A strong sense of self-efficacy enhances accomplishment, enabling one to master challenges rather than see them as threats (Bandura, A., 1994). In this study, the sources of self-efficacy examined were Mastery Experiences, Social Persuasion, Somatic/Emotional Experiences, and Vicarious Experiences. The participants scored the items related to various aspects of their project work. Their self-efficacy was strongly influenced by Mastery Experiences, which enabled them to perform tasks such as organising, planning, and setting goals. The sense of accomplishment from Mastery Experiences such as organisational skills, knowing how to do research and gaining skills such as thinking logically and communicating effectively, featured most prominently. However, the median for “Knowledge gained” was undecided. For this category, six out of ten participants were not confident that their knowledge helped them accomplish PBL tasks. Specifically, for the items, “I really believe I am a quick thinker, I tend to look at things differently than others my age, and I was knowledgeable about the topic” 60% of the participants were undecided. From the interviews, it was established that these participants did not believe that they had the required knowledge for completing the PBL tasks. It appeared that lacking the requisite knowledge did not deter the participants from attempting the PBL tasks. Overall, the participants’ self-efficacy stemmed from their belief that they had the necessary inquiry skills to complete the PBL tasks. The implication for developers of PBL tasks is the need to develop the inquiry skills of learners, and not necessarily their content knowledge because being unfamiliar with a new knowledge area does not directly affect their self-efficacy beliefs. These findings are similar to that of Britner & Pajares (2006) who found that there was a strong influence of Mastery Experiences on school science learners’ self-efficacy beliefs. They claimed that developing inquiry oriented learning experiences would further develop their self-efficacy beliefs. Agustiani et al. (2016) found that there was a strong correlation between self-efficacy beliefs of students and self-regulation. Mastery Experiences were found to be the most influential source of self-efficacy in other studies (Bandura, A. et al., 2001, Britner, S. & Pajares, F., 2006, Hutchison-Green, M. et al., 2008). In this study, Mastery Experiences, specifically inquiry skills were the main sources of self-efficacy for the participants and these were also necessary for them to perform PBL tasks.

Social Persuasion (feedback and recognition) that were most influential on their self-efficacy beliefs were Expo as an institution and family members. In the interviews, it was confirmed that the participants were most influenced by the recognition they got from family members and Expo. The recognition received from Expo in the form of awards and the confirmation received from family members were most valued by all ten participants and were identified as the main sources of Social Persuasion. The next highest source of Social Persuasion was recognition by their peers at school. Teachers and Expo Judges were not identified as strong sources of recognition. Teachers and schools need to provide feedback and recognise the efforts of learners. Five of the ten learners believed that they did not get sufficient feedback from Judges at Expo. Recognising the efforts of learners in PBL is important for the development of their self-efficacy beliefs (Hutchison-Green, M. et al., 2008). Specifically, the persuasion from social sources are important for children's' self-belief and hence performance (Bandura, A., 1994).

Somatic or emotional experiences that were most influential on the participants' self-beliefs were feelings of confusion, anxiety and confidence. Probing during the interviews revealed that the participants experienced most anxiety and confusion at the *Forethought Phase* of the project. At this initial phase, the participants struggled with initiating the project, becoming confused and frustrated. Their confidence increased after successfully completing stages of the PBL tasks. Being fearful of the project task or failing and feelings of embarrassment did not affect their self-efficacy for the project work. According to Bandura (1994) if emotional states such as fear of failing do not affect self-efficacy then it is an indication that the person has a high sense of efficacy.

Vicarious Experiences refer to the social models that influence learners' self-efficacy beliefs and are regarded as the most complicated source of self-efficacy. In this study, the participants' source of self-efficacy were their peers at school and family members. The participants regarded family members as role models, admiring their achievements more than that of their peers at school. The learners at Expo were examples of success and the participants regarded them as role models. Both Scientists and Expo Alumni were selected as least influential to their self-efficacy. In the interviews, it was established that the participants did not have access to Scientists or Expo Alumni as role models. Bandura states that modelling is very effective in increasing self-efficacy beliefs of learners (Bandura, A. et al., 2001). Britner & Pajares (2006) stated that due to learners having limited mastery experiences upon which to base their efficacy judgements, Vicarious Experiences and Social Persuasion become very important. The implications for schooling and Expo is that more role models such as Scientists and especially Expo Alumni should be made accessible to participants to help boost their self-efficacy.

To answer the second research question on which self-regulated learning strategies were used in the completion of the project-based tasks, data was gathered through semi-structured interviews. It was first established that all ten participants engaged in PBL and not just project work, that is, all PBL tasks involved a driving question/problem and a series of activities that result in products or solutions (Blumenfeld, P. et al., 2006). One of the issues with PBL is that the learners have to be cognitively involved with the subject matter over extended periods of time in order to investigate complex phenomena through complex tasks. All participants in this study were engaged with their PBL tasks for up to a year and participated in Expo a minimum of two times. PBL has three phases, each associated with corresponding phases of SRL. The *Project or Problem Launch Phase* of the PBL tasks is related to the *Forethought Phase* in SRL; the *Guided*

Inquiry Phase of PBL is linked to the SRL *Performance Phase*; and the last Phase of SRL occurs in the *Project/Problem Conclusion Phase* of PBL (English, M. & Kitsantas, A., 2013).

Using English & Kitsantas' Model of PBL and SRL, key attributes of each of the phases were identified. The interview questions centred around exploring the context, task value, goal setting and time management during the *Forethought Phase*. For the *Performance Phase*, the guided inquiry done by the participants were examined in terms of the assistance they sought, their perception of difficulty of the PBL tasks, how they organised their work, and the choices they made. The final *Phase of Reflection* in the *Project/Problem Conclusion Phase* of PBL was explored in terms of the reflection done after the PBL tasks were completed and their participation in Expo ended. From a social cognitive perspective, SRL is viewed as the interaction of the personal, behavioural, and environmental aspects, and the personal processes involve knowledge, metacognition, and goal setting. In addition, SRL involves self-evaluation, modelling and verbal persuasion (Zimmerman, B., 2002, Sungur, S. & Tekkaya, C., 2006). This reflective study was limited to examining only goal setting, time management, self-reflection and metacognition of the SRL experiences through recall.

All ten participants were introduced to PBL through their participation in Expo. Six participants were familiar with only the process of scientific investigations and all ten participants indicated that they were not prepared for the complexity or difficulty and demands of the tasks as well as the high levels of self-regulation required. Three of the learners were introduced to Expo through their teachers or schools but beyond this, they did not received further support. These three learners, together with two other learners indicated that despite the minimal involvement of their teachers, their projects were assessed at school for internal assessments. Eight out of ten participants identified their ability to organise, set goals and plan as the most important reasons for their success with PBL tasks. This confirmed the findings on the influence of the Mastery Experiences, which enabled them to perform tasks such as organising, planning, and setting goals, and these gave them a sense of accomplishment. In addition, all ten participants expressed having valued the PBL tasks, that is, they saw value in the Expo PBL activities. Sungur & Tekkaya (2006) identified high task value and goal orientation as key attributes of PBL learners. Five of the ten participants identified time management as their SRL strategy. However, the participants were not aware of their thinking processes or choices made during the execution of the PBL tasks. This indicated that metacognition which is an important aspect of SRL did not feature in the SRL strategies used by the participants. Of the three aspects of SRL identified by Zimmerman (2002), that is, metacognition, motivation and behaviour, only behavioural aspects such organising, time management and goal setting emerged in this study. All ten participants sought social assistance for the PBL tasks from structures outside of school that are family and other mentors. The support received by three of the participants from their *teachers* were during the *Performance Phase* and not during the *Problem Identification Phase.* This finding supported the finding that the Somatic Experiences of anxiety and confusion experienced by the participants were increased during the *Forethought Phase.* English & Kitsantas (2013), state that for successful PBL the *Forethought Phase,* which involves *Problem Identification* is the critical phase where maximum guidance from the teacher is required. Nine of the participants claimed that there were no assistance from teachers during the first phase of PBL and experienced this phase as being most difficult. Their self-efficacy beliefs associated with this phase included anxiety and confusion. Pajares and Valiante (2002) identified most failure and abandonment of PBL tasks at this phase. Hence, the SRL strategies for the forethought phase needs more structured interventions and guidance from teachers. Only two of the ten participants, mentioned that they engaged in self-evaluation at the end of the PBL task. However, this self-evaluation was superficial and related mostly to the outcomes achieved rather than the processes involved. There is a need for self-evaluation of SRL strategies during the different phases of PBL to enable learners to become efficacious learners.

While other studies found that self-efficacy beliefs influenced learners' career choices, this aspect could not be established from this study. The participants mentioned that enjoying science and their academic performance influenced their science career paths. Although it was not the focus of this study, no correlation was found between the quintile ranking of the school or the gender of the participants and their self-efficacy beliefs. One of the limitations of this study is that the self-reflective method used relied on the memory of the participants and hence there may have been reporting bias. While there are several rating scales for self-efficacy and self-regulated learning, scales which are specific for PBL activities such as Expo were not found. Hence, the reliability of the scales for Expo activities could not be established. In addition, the internal validity of the scale items could not be established statistically because of the small number of participants and small number of items of the scale. Recommendations arising out of this study include structured interventions that focus on skill development, particularly inquiry skills. In addition, when completing project-based tasks, learners require increased support from teachers during the initial stage. This stage has been identified as being critical to successful completion of the tasks. Learners' self-efficacy beliefs are also influenced by the feedback and support received. Hence, schools should provide this feedback and support because if learners do not have access to such resources outside the school, they would be disadvantaged. Areas for further research identified from this exploratory study include correlation studies between the SRL and self-efficacy beliefs in terms of gender, academic performance, or access to resources. Studies with larger and more diverse samples would add to the knowledge base on self-regulation and self-efficacy beliefs in Project-Based Learning.

Conclusion

In Project-Based Learning, the learner takes responsibility and drives their own learning. This requires the learner to operate at a high level of self-regulation. Related to self-regulation is the learner's self-efficacy beliefs, and together these influence the performance in project-based tasks. In this study of ten participants, the self-efficacy beliefs of Mastery Experiences were most influential in the performance of the project-based tasks. Skills related to organisation, research, and inquiry strongly influenced their self-efficacy beliefs, while the participants were least affected by their lack of new content knowledge to complete the tasks. Regarding Social Persuasion, the participants received most support and recognition from their families and Expo as an institution. The Somatic Experiences of anxiety and confusion were most prominent during the initial phases of the project-based tasks, supporting the finding that the participants experienced most difficulty during the *Forethought Phase* of self-regulation. The sources of Vicarious Experiences such as role modelling were mostly from their families and persons outside of school who provided support, especially during the *Forethought Phase*. In terms of self-regulation, self-evaluation, reflection, and metacognitive activities were least practiced by the participants. The participants also indicated that they were not prepared for the complexity and difficulty of the tasks, and the demands of taking responsibility for their own learning. However, all participants agreed that the successful completion of the tasks positively influenced their self-efficacy beliefs. The results indicate that Project-Based learning activities does support the development of self-regulation and can positively influence self-efficacy beliefs, both of which are required for promoting successful educational outcomes. One such project-based activity with such potential is Expo. However, key areas related self-regulation and self-efficacy when completing Expo tasks need to be addressed through structured interventions.

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Appendix A: Description of the Participants

Participant	Province	Participation in Regional &/or National Expo	Age in years	Area of Study	Gender	Race	Type of School
1	North West	2016, 2017, 2018	20	BSc Biology	F	African	Urban Township, Quintile 4
2	Gauteng	2016, 2017 2018	19	Engineering	M	White	Private
3	Northern Cape	2017, 2018	19	Medicine	F	White	Urban , Quintile 5
4	Mpumalanga	2017, 2018	20	Engineering	M	African	Rural, Quintile 1
5	Gauteng	2016, 2017, 2018	21	Engineering	M	African	Urban, Quintile 5
6	KwaZulu-Natal	2016, 2017, 2018	19	Engineering	M	Indian	Urban, Quintile 5
7	Western Cape	2016, 2017	19	Medicine	F	White	Private
8	Limpopo	2016, 2017	20	Pharmacy	F	African	Rural Quintile 1
9	Free State	2016, 2017, 2018	20	Clinical Psychology	F	African	Urban Township, Quintile 4
10	Eastern Cape	2017, 2018	19	BSc	M	Coloured	Urban, Quintile 5

Appendix B: Self-Efficacy Questionnaire

Dear participant,

Thank you for agreeing to participate in this study. You have been selected to participate in this study because you are a past Expo participant and you are currently studying in a STEM (Science, Technology, Engineering, and Mathematics) field.

This Questionnaire is Confidential. Eskom Expo for Young Scientists will use the data from this Questionnaire for the purposes of understanding Project-Based Learning, with the intention of improving practice. No actual names will be used. This is not a test of your ability nor is it assessing your successes. Hence, it would be appreciated if you could provide a true reflection of your experiences. Since this is a reflective study, please answer as best as you can - as you remember the details. There are no right or wrong answers. You are under no obligation to answer the questions and can withdraw from this study whenever you wish to.

A. TELL US ABOUT YOURSELF

A.1 Which year did you matriculate?

A.2 Which school did you matriculate from?

A.3 How would you describe this school? Select whichever applies: Private, Government, ex-African, ex-Indian, ex-Coloured, ex-White, township school, urban school, rural school

A.4 How would you describe your Grade 12 performance at school: A, B, C, D or E?

A.5 How would you describe your performance in Grade 12 Mathematics: A, B, C, D or E?

A.6 How would you describe your performance in Grade 12 Physical Sciences: A, B, C, D or E?

A.7 How would you describe your performance in Grade 12 English: A, B, C, D or E?

B. TELL US ABOUT YOUR EXPO PROJECT

Which year(s) did you participate in Expo?

What was your project about? One sentence is sufficient

Complete the Table below regarding your Expo participation:

Year(s)	School, Regional, National, International Expo?	Achievements
e.g. 2014	e.g. Regional and National	e.g. Bronze at Regional, Silver at National

B.1 How did you hear about Expo? Who introduced you to Expo?

B.2 Was it compulsory to participate in Expo at your school? If yes, did it count towards any marks?

B.3 Did your teacher/s play any role in your Expo project?

B.4 Where did you get the idea for your Expo project topic?

B.5 Is there one person who stands out as the most influential person in terms of helping you with your Project? If yes, who is this person?

B.6 What is your current field of study?

C. Regarding your Expo participation, for each of the statements listed below, select whether you Strongly Disagree, Undecided, Agree, or Strongly Agree. Indicate your selection with a **X**

No	Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1	I could to sift through large amounts of written work/literature because I am good at organising my thoughts					
2	I am good at planning					
3	I can set goals/deadlines e.g. finish the data analysis this weekend					
4	I believe I am a quick learner					
5	I tend to look at things differently than others my age					
6	I was knowledgeable about the topic					
7	I was able to learn how to identify variables					
8	After doing the research project, I now know where to start with research					
9	From the experiences with my project work, I now know how to do research					
10	My science project was doable because of the skills I have					
11	The soft skills that I learnt e.g. rewriting words/ideas in my own words is very useful					
12	One of the skills that helped me with my project was how to think logically					
13	After all my project work, I still don't feel confident to talk to people (reversed)					
14	I can now speak confidently about my research project					
15	My confidence helped with my project work					
16	When I saw that other learners at school were doing with projects, it interested me					
17	At school I realised that, "if they can do it, then so can I"					

18	I was not influenced to do Expo by learners from my school					
19	I wish my teachers could have shown some interest in my work					

No	Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
20	My teacher/s always made me feel like I was a scientist					
21	My teachers helped me and my school recognised my work					
22	If only the judges encouraged me, I think I could have done so much better					
23	To me it mattered that the judge/s saw how hard I worked					
24	It really meant a lot when the judge/s said that my science project was valuable					
25	I learnt a lot from other learners at Expo					
26	By interacting with other learners at Expo, I learnt a lot					
27	I worked harder on my project when I saw what other learners accomplished at Expo					
28	My parents/family supported me when I wanted to give up					
29	My family did not get involved in my Expo work					
30	My family assisted me with resources and logistics					
31	I admired the Expo work done by learners at school					
32	I learnt how to do research from learners at school					
33	Learners at my school did really good projects					
34	I admired the achievements of other learners at Expo					
35	I wanted to be like the other learners at Expo					
36	Learners at Expo did not know how to do research					
37	I know of many past Expo participants					
38	I get inspired whenever I hear a past participant					
39	I learnt something from at least one past participant					
40	I want to be like others in my family					
41	I am proud of my family members					

42	I admire my family members for their accomplishments					
43	I know at least one scientist					
44	At least one scientist was interested in my work					
45	I admire at least one scientist					

No	Statement	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
46	Thinking about Expo judges reminds me of being fearful					
47	I think that my Expo experiences were bad					
48	Most learners experienced fear at Expo					
49	I was embarrassed when I did not win					
50	I did not show others my project because it was not good enough					
51	When I did not win I could not face my friends/family					
52	I remember feeling confused most of the time					
53	I was most confused when starting my project					
54	I was most confused when I started to write my research					
55	I still feel stressed when reminded about my Expo project					
56	I have such good memories of doing my Expo project					
57	The Expo experience is stressful					
58	I loved the fact that I was going into the unknown with my project					
59	Learning something that other learners in my class didn’t know made me feel good					
60	After participating in Expos, I still don’t feel like I can do research					

Appendix C. Semi-Structured Interview Schedule for Self-Regulated Learning

A. FORETHOUGHT

Context

How did you learn to do research projects/investigations?

Task value

Why did you do the Expo project?

Goal Setting

Did you set goals for yourself? If yes how? If no, why not?

Time Management

How did you managed your time? Which part of your project did you spend more time on?

PERFORMANCE & CONTROL

Who helped you throughout your project and how?

Perception of difficulty

Did you experience difficulty in any part of your work? If yes which part?

Organising work

Did you meet all your deadlines and how did you organise your work?

Choices

Did you make any sacrifices to enable you to complete your project? If yes. Explain

REFLECTION

Did you reflect on your project work done? If yes, at what stages did you reflect on your work? After competing at Expo, did you make any changes suggested by judges?

Why did you choose a career in science?

Appendix D Aggregated responses from the Questionnaire

Research Question 1: What were the sources of the participants' self-efficacy beliefs, in the context of the Expo Project-Based Learning tasks completed?

Mastery Experiences

Organisational Experiences
1. I could to sift through large amounts of written work/literature because I am good at organising my thoughts
2. I am good at planning
3. I can set goals/deadlines e.g. finish the data analysis this weekend

Knowledge
4. I really believe that I am a quick thinker
5. I tend to look at things differently than others my age
6. I was knowledgeable about the topic

Learnt how to do research
7. I was able to learn how to identify variables
8. After doing the research project, I now know where to start with research
9. From the experiences with my project work, I now know how to do research

Gained Skills
10. My science project was doable because of the skills I have
11. The soft skills that I learnt e.g. rewriting words/ideas in my own words is very useful
12. One of the skills that helped me with my project was how to think logically

Communication Skills
13. After all my project work, I still don't feel confident to talk to people (reversed)
14. I can now speak confidently about my research project
15. My confidence helped with my project work

Social Persuasion

Learners at School
16. When I saw that other learners at school were doing with projects, it interested me
17. At school I realised that, "if they can do it, then so can I"
18. I was not influenced to do Expo by learners from my school (reversed)

Teachers and School
19. I wish my teachers could have shown some interest in my work (reversed)
20. My teacher/s always made me feel like I was a scientist
21. My teachers helped me and my school recognised my work

Judges at Expo
22. If only the judges encouraged me, I think I could have done so much better (reversed)
23. To me it mattered that the judge/s saw how hard I worked
24. It really meant lot when the judge/s said that my science project was valuable

Learners at Expo
25. I learnt a lot from other learners at Expo
26. By interacting with other learners at Expo, I learnt a lot
27. I worked harder on my project when I saw what other learners accomplished at Expo

Family
28. My parents/family supported me when I wanted to give up
29. My family did not get involved in my Expo work (reversed)
30. My family assisted me with resources and logistics

Vicarious Experiences
Learners from my School
31. I admired the Expo work done by learners at school
32. I learnt how to do research from learners at school
33. Learners at my school did really good projects

Learners from Expo
34. I admired the achievements of other learners at Expo
35. I wanted to be like the other learners at Expo
36. Learners at Expo did not know how to do research (reversed)

Learners who are Expo Alumni
37. I know of many past Expo participants
38. I get inspired whenever I hear a past participant
39. I learnt something from at least one past participant

Family
40. I want to be like others in my family
41. I am proud of my family members
42. I admire my family members for their accomplishments

Scientists
43. I know of at least one scientist
44. At least one scientist was interested in my work
45. I admire at least one scientist

Somatic Experiences
Fear
46. Thinking about Expo judges reminds me of being fearful
47. I think that my Expo experiences were bad
48. Most learners experienced fear at Expo

Embarrassed
49. I was embarrassed when I did not win
50. I did not show others my project because it was not good enough
51. When I did not win I could not face my friends/family

Confused

52. I remember feeling confused most of the time
53. I was most confused when starting my project
54. I was most confused when I started to write my research

Anxiety
55. I still feel stressed when reminded about my Expo project
56. I have such good memories of doing my Expo project (reversed)
57. The Expo experience is stressful

Confident
58. I loved the fact that I was going into the unknown with my project
59. Learning something that other learners in my class didn't know made me feel good
60. After participating in Expos, I still don't feel like I can do research

Likert Scale: 1 = Strongly Disagree 2 = Disagree 3 = Undecided 4 = Agree 5 = Strongly Agree

MASTERY EXPERIENCES: Which accomplishments were achieved?

Participant	Work habits	Knowledge	Research	Skills	Communication
1	5	3	5	4	4
2	5	5	4	4	5
3	4	3	5	5	4
4	5	4	5	5	5
5	4	4	4	4	4
6	5	5	5	5	4
7	4	3	4	4	3
8	4	3	4	4	3
9	4	3	3	4	3
10	4	3	4	4	3

SOCIAL PERSUASION: What were the sources of recognition?

Participants	Learners	Teachers/School	Judges	Expo	Family
1	4	2	2	5	4
2	3	4	4	4	5
3	3	5	4	5	5
4	4	4	4	4	5
5	4	3	4	4	5
6	5	4	3	5	5
7	5	4	4	5	5
8	4	2	2	5	5
9	3	2	2	5	5
10	4	2	4	5	5

VICARIOUS: Who influenced you most (Role Models)?

Participants	Learners at School	Learners at Expo	Learners: Alumni	Family	Scientists
1	5	4	1	3	1
2	5	4	1	5	1
3	4	5	4	5	1
4	4	5	4	5	2
5	2	2	5	5	5
6	2	2	5	5	5
7	1	5	1	4	3
8	1	5	1	4	1
9	1	4	1	4	1
10	1	4	1	5	1

SOMATIC/EMOTIONAL: Which experiences do you associate with your Expo project?

Participants	Fear	Embarrassed	Confused	Anxiety	Confident
1	2	1	4	1	5
2	1	1	4	1	5
3	1	1	3	1	3
4	1	1	2	1	4
5	3	2	2	1	5
6	3	1	1	2	5
7	3	1	1	2	4
8	2	2	4	2	5
9	2	1	4	1	4
10	2	1	4	1	4

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The South Africa Agency for Science and Technology Advancement (SAASTA) is a business unit of the National Research Foundation (NRF) with the mandate to advance public awareness, appreciation and engagement of science, engineering, innovation and technology in South Africa. Science, through research, has a crucial role to play in the growth of South Africa's economy. Active dialogue and engagement between science and society ensures that scientific research findings are easily translated into relevant, appropriate and beneficial innovation and entrepreneurial opportunities. Research findings should also have an impact on policy and social conditions in a country. This can only be achieved when science becomes a daily dialogue and discourse. The fundamental principles of SAASTA's success in advancing a culture of engagement with science in South Africa lies in its synergistic approach. SAASTA initiatives fall under three key strategic areas:

- Science Education, through which we build up the supply of tomorrow's scientists and innovators;
- Science Awareness, through which we engage the public with the phenomena of science, engineering and technology; and
- Science Communication, through which we share science and technology achievements with the public, building up their appreciation and benefits of science.

The three areas are interdependent, each enhancing the effectiveness of the other, while accommodating different target audiences and creating opportunities for joint initiatives across several government departments, higher education institutions, science councils, science centres and other science agencies.

Science advancement is integrated in every level of the business of the NRF; SAASTA, the National Research Facilities (that focus on the fields of astronomy, biodiversity and conservation, and nuclear sciences) and the Research, Innovation Support and Advancement office (that supports research, researchers and the provision of world-class research infrastructure through a grant-making programme) are implementing a cross-cutting science engagement plan.

Mission	Vision
To advance public awareness, appreciation of and engagement with science, technology, engineering, mathematics and innovation in South Africa.	NRF-SAASTA aims to be the leading science advancement agency communicating the value and impact of science and technology in a dynamic knowledge economy, and simultaneously building the science, engineering, and technology human resource based in South Africa.

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