# S.T.E.M.I

## Olympiads and Competitions
*Community of Practice*
## Conference

# 2017

National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

# TABLE OF CONTENT

## STEMI Olympiads and Competitions Community of Practice Conference Proceedings 2017

# THE CONFERENCE

## STEMI COMMUNITY OF PRACTICE CONFERENCE

### BACKGROUND

Education and training, research and development are some of the key elements of the National System of Innovation (NSI). One of the major challenges facing our science system is inadequate renewal of the science, engineering, and technology (SET) human capital and making it representative of the country's demographics. It is against this background that the Department of Science and Technology (DST) initiated the Youth into Science Strategy (YISS). This strategy aims to broaden the pool of matriculants with passes in Mathematics and Science, appropriate to enter for science-based degree studies at higher education institutions and ultimately increase the SET capital in South Africa.

Central to the implementation of the YISS is the use of science, technology, engineering, mathematics and innovation (STEMI) Olympiads and Competitions as instruments to identify learners with potential to follow SET careers. Through this programme the DST intends to provide funding to existing Olympiad and Competition Organisers to increase the number of learners participating in Olympiads and Competitions, as well as coaching mentors and/or educators to support these learners.

The STEMI Olympiads and competitions programme targets the following:

Learners from grade one to twelve in remote disadvantaged areas, including urban areas (townships) with the objective of increasing the footprint (covering municipal districts with limited prior coverage) of participation, mentoring, and coaching.

To provide educator training workshops on STEMI Olympiads and Competitions, as well as training and support for mentors.

Conceptualisation of a strategy towards the establishment of a community of practice for STEMI Olympiads and Competitions.

### CONFERENCE SCOPE

The **STEMI Olympiads and Competitions Community of Practice Conference** is an annual 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 Competition organisers and other industry stakeholders together to present academic and non-academic research 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.

# 2017 STEMI Olympiads and Competitions Community of Practice Conference

## 14 – 16 March 2017

| DAY 1 | | | |
|---|---|---|---|
| Moloko Matlala | | | |
| **Activity** | **Delegate** | **Venue** | |
| Registration | All | Registration Table | |
| Exhibit walkthrough | | Exhibition Area | |
| Lunch | All | Dining Hall | |
| Opening and welcome | NRF | Main Venue | |
| Plan of Action from 2016 & Objectives of the 2017 Conference | Mr Bersan Lesch<br>Deputy Director: DST Science Promotion | Main Venue | |
| Flowing from the 2016 STEMI COP conference and looking ahead, a Plan of Action is presented to the COP for consideration. The objectives of the conference will also be presented. | | | |
| Participant Feedback from the 2016 STEMI Olympiads and Competitions Community of Practice Conference | Mrs Joyce Khunou<br>M&E Manager: SAASTA | Main Venue | |
| At the 2016 STEMI Olympiads and competitions COP an evaluation was done, and the feedback provided, will be shared with the 2017 COP conference delegates | | | |
| Recommendations of the 2016 Conference: What has been achieved so far | Mr Moloko Matlala<br>Science Education Manager: SAASTA | Main Venue | |
| The progress made since the 2016 COP conference. | | | |
| Message from ASTEMI EXCO | Mrs Marinda Jordaan<br>ASTEMI Chairperson | Main Venue | |
| The Association for STEMI Olympiads and competitions (ASTEMI) is an umbrella body with 16 founding member organisations represented across the spectrum including mathematics, technology and engineering. ASTEMI held its AGM as a preconference event, and the Chairperson will share a message with the COP delegates. | | | |
| Introduction of the Guest Speaker | Programme Director | Main Venue | |

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|---|---|---|---|
| 14:15 – 14:40 | Keynote Address | Vuyiswa Ncontsa<br>CEO<br>BRIDGE | Main Venue |
| | Ms Ncontsa is the CEO of Bridge. Bridge is an NPO with membership of more than 3000 people representing 650 organisations. Bridge members collaborate in 12 Communities of Practice and host more than 60 face-to-face COP dialogues per year.<br><br>Ms Ncontsa held prominent positions at Teach SA and the Centre for Education Policy Development and the School Capacity Innovation Programme among others. She has experience in philanthropy and public-private partnerships with international agencies and corporations. | | |
| 14:40 – 15:00 | Afternoon Tea Break &<br>Exhibition | All | Exhibition Area |
| 15:00 – 15:15 | Preconference Evaluation | Mrs Joyce Khunou<br>NRF/SAASTA | Main Venue |
| 15:15 – 15:30 | Presentation:<br>**Discovering Innovation Through Research** | Ms Rachel Rayner<br>Australian Volunteers International | Man Venue |
| | Rachel is on an 18-month stint for the Australian Volunteers International (AVI) in South Africa. She has extensive experience at science centres (National Science and Technology Centre & the Discovery Science and Technology Centre) working in Australia and Vietnam, doing science shows, workshops and exhibitions. She was a Science Communication Fellow with the Ocean Exploration Trust. | | |
| 15:30 – 15:45 | Presentation:<br>**Olympiads in the Digital Data Age** | Mr Case Rijsdijk<br>SA Physics Olympiads | Main Venue |
| | Case is a retired educator, astronomer and physicist, though still very actively involved with the South African Institute of Physics (SAIP) and other professional bodies. He has presented more than 60 papers at national and international conference, authored and co-authored books, textbooks and workshop manuals. He has delivered well over a 100 public lectures on Physics and Astronomy. | | |
| 15:45 – 16:00 | Presentation:<br>**Analysis of Performance of Grade 12 learners with emphasis on Mathematics and Physical Sciences – What impact can the Olympiads and competitions have?** | Mr Moloko Matlala<br>NRF/SAASTA | Main Venue |
| | Moloko is the Manager of the Education unit at SAASTA. | | |
| 16:00 – 16:15 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 16:15 – 16:30 | Presentation:<br>**A cross sectional comparative study into gender and school's setting on attitudes towards mathematics: A case of selected schools in the Eastern Cape** | T Kwangwari, CS Marange and CK Hlatywayo<br>University of Free State | Main Venue |
| 16:30 – 16:45 | Presentation:<br>**For the love and fear of statistics"" students attitudes and experiences towards statistics at rural university in the Eastern Cape Province of South Africa** | WT Chinyamurindi and SW Gomera<br>University of Fort Hare | Main Venue |
| | Prof Willie Chinyamurindi is Associate Professor in the Department of Business Economics at UFH. His research focus is on human capital development, career management and use of qualitative methodology within the management sciences. | | |

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|---|---|---|---|
| 16:45 – 17:00 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 17:00 – 17:15 | Demonstration:<br>**STEMI Community of Practice Online Platform** | Mr Chipa Maimela NRF/ SAASTA | Main Venue |
| 17:15 – 17:20 | Announcements | Programme Director | Main Venue |
| 18:00 – 20:00 | Dinner served | Hotel guests only | |

| **DAY 2** | | | |
|---|---|---|---|
| **Programme Director** | Mr Bersan Lesch | | |
| **Slot** | **Activity** | **Delegate** | **Venue** |
| 06:30 – 07:30 | Breakfast served | Hotel Guests only | Dining Hall |
| 07:00 – 07:50 | Morning Tea | Non-Guests | Registration Area |
| 08:00 – 08:10 | Opening and Welcome | Programme Director | Main Venue |
| 08:10 – 08:30 | Presentation:<br>**Report on the Mathematics Olympiads Indaba** | Prof Johann Engelbrecht South African Mathematics Foundation | Main Venue |
| | A pre-conference indaba on Mathematics Olympiads and competitions were held with various stakeholders. | | |
| 08:30 – 08:45 | Presentation:<br>**Science Communications Competition in SA** | Ms Joanne Riley NRF/SAASTA | Main Venue |
| 08:45 – 09:00 | Presentation:<br>**Virtual Get excited about Robotics (GEAR) Competition** | Tanja Karp, Patricia Gouws & Kabelo Pheeha UNISA | Main Venue |
| | Dr Tanja Karp is Associate Professor of Electrical and Computer Engineering at Texas Tech University, Lubbock, Texas. She is a U.S. Fulbright Scholar at UNISA. Previously, she was a senior researcher and teaching associate at Mannhein University in Germany. She has published more than 75 journal and conference papers. She received several awards for her excellence in teaching and her robotics programmes for learners.<br><br>Kabelo is an experienced judge in robotics competitions; head judge for the Open European championships, Africa Open Championships and SA First Lego league (national) and several other regional and local events. He mentors students and ambassadors I-SET at UNISA. | | |
| 09:00 – 09:15 | Presentation:<br>**Explore it, play it, question it, Igniting an early interest in STEMI** | Mr Brent Hutcheson Centre for Education | Main Venue |

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|---|---|---|---|
| 09:15 – 09:30 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 09:30 – 09:45 | Presentation:<br>**Participation and Challenges in International Physics Olympiad (IPHO) and International Chemistry Olympiad (ICHO)** | Dr M. Moodley and Mr Ajay Bissessur<br><br>UKZN | Main Venue |
| | Dr Moodley is physics lecturer at the University of KwaZulu-Natal. He is the recipient of the NRF Prestigious scholarship for an overseas doctorate. He was instrumental in the establishment of the Centre for Quantum Technology and the Quantum Research Group at UKZN. He is principal coach for the South African Physics Olympiad team and examiner of the National Physical Science Olympiad.<br><br>Ajay Bissessur is a Chemistry lecturer at UKZN. He was chairperson of the Scientific committee that hosted the International Junior Science Olympiad in SA. He is member of the International Chemistry Olympiad Committee and team mentor for the South African team. He does the public relations for the School of Chemistry and involved in various outreach activities. | | |
| 09:45 – 10:00 | Presentation:<br>**SARASSEM as a resource for AstroQuizz** | Prof R Medupe<br>North West University | Main Venue |
| | Prof Medupe is Professor of Physics and Astronomy. He has published more than 50 papers on Astrophysics and the history of Astronomy in Africa. He has written non-technical books for children and learners. He is Chairperson of the national Astrophysics and Space Science Programme Consortium. He is a member of the Astronomy Advisory Council of the NRF and of the South African Astronomical Observatory Advisory Board. | | |
| 10:00 – 10:15 | **Validity and diagnostic attributes of the SAMO Junior second round** | Prof Johann Engelbrecht<br>SAMF | Main Venue |
| | Professor Engelbrecht is Executive Director of the South African Mathematics Foundation. He was instrumental in the establishment of the SAMF as well as for South Africa hosting the International Mathematics Olympiad in 2014. He is Emeritus Professor of Mathematics at University of Pretoria and was Deputy Dean: Teaching, Learning and Community Engagement. | | |
| 10:15 – 10:30 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 10:30 – 10:45 | Morning Tea Break<br>Exhibition | All | Exhibition Area |
| 10:45 – 11:00 | Presentation:<br>**STEM readiness for school development** | Mr Parthy Chetty<br>Executive Director: Eskom Expo for Young Scientists | Main Venue |
| | Parthy is a teacher by profession, taught at high school level in Durban, worked in the Gauteng Department of Education and a Deputy Chief Education Specialist in the national department. He is the Executive Director of the Eskom Expo for Young Scientists. He previously headed education initiatives of the Intel Corporation in South Africa which expanded into Africa. | | |
| 11:00 – 11:15 | Presentation:<br>**Diamonds in the sky: Harnessing Olympiads and competitions for astronomy development in Africa** | Ms Anja Fourie<br><br>SKA | Main Venue |
| 11:15 – 11:30 | Presentation: Impact of the Eskom Expo | Mr Kholiswa Ntshinga<br>Former Eskom Expo Participant | Main Venue |

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|---|---|---|---|
| 11:30 – 11:45 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 11:45 – 12:00 | Presentation: **Monitoring & Evaluation Framework (STEMI Olympiads and Competitions)** | Isaac Ramovha Director: Science Promotion DST | Main Venue |
| 12:00 – 12:30 | Briefing for Parallel Sessions | Programme Director | Main Venue |
| 12:30 – 13h30 | Lunch | All | Dining Hall |
| 13h30- 15h00 | Parallel Sessions | | |
| 15:00 – 15h15 | Tea | | |
| 15:15 – 15:30 | Report Back: Group A | | Main Venue |
| 15:30 – 15:45 | Report Back: Group B | All | Main Venue |
| 15:45 – 16:15 | Discussion: Questions, Comments & Responses | | |
| 16:15 – 16:30 | Report Back: Group C | | Main Venue |
| 16:30 – 16:45 | Report Back: Group D | All | Main Venue |
| 16:45 – 17:15 | Discussion: Questions, Comments & Responses | All | Main Venue |
| 17:15 – 17:20 | Announcements | Programme Director | Main Venue |
| 18:00 – 20:00 | Dinner | Hotel Guests | Dining Hall |

| DAY 3 | | | |
|---|---|---|---|
| **Programme Director** | Mr Moloko Matlala | | |
| **Slot** | **Activity** | **Delegate** | **Venue** |
| 06:30 – 07:30 | Breakfast served | Hotel Guests | Dining Hall |
| 07:30 – 08:20 | Check-out | Hotel Guests | Reception |
| 07:30 – 08:20 | Morning Tea | Non-Guests | Registration Area |
| 08:30 – 08:40 | Opening and Welcome | Programme Director | Main Venue |
| 08:40 – 09:30 | Summary of the Conference Proceedings:<br>Plenary Recommendations<br>Panel Discussions Recommendations<br>Feedback from Parallel Sessions | Mr Moloko Matlala<br>NRF/SAASTA | Main Venue |
| 09:30 – 09:45 | Key Deliverables: Short to Long Term | Mr Bersan Lesch<br>DST | Main Venue |
| 09:45 – 10:15 | Morning Tea Break | All | Exhibition Area |
| 10:15 – 10:45 | Evaluation of the 2017 Conference Objectives | Mr Isaac Ramovha<br>Director: DST Science Promotion | Main Venue |
| 10:45 – 11:25 | Post Conference Evaluation | Mrs Joyce Khunou<br>NRF/SAASTA | Main Venue |
| 11:25 – 11:45 | Vote of Thanks | Mr Moloko Matlala<br>NRF/SAASTA | Main venue |
| 12:30 – 13:00 | Lunch | All | Dining Hall |
| 13:30 | Departure | All | |

# An empirical cross-sectional analysis on attitudes towards mathematics. A case of selected high schools in the Eastern Cape Province of South Africa

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## Abstract

Learners' success in mathematics depends on the attitude towards Mathematics. This study tends to look at the effect of attitude towards Mathematics (confidence and enjoyment), and English as the medium of instruction influence achievement in Mathematics. The school settings (rural and urban) was also evaluated to see how it affects performance in Mathematics. The study was based on a survey of high school learners' in the Eastern Cape Province of South Africa. Sample of the study was 500 learners (male = 241 and female = 259) from grade 10 to 12. A stepwise multiple regression model revealed that, performance in English ($\beta_1$ = 0.645; t = 18.444; p = <0.0001), confidence ($\beta_2$ = 6.631; t = 7.024; p = <0.0001) and enjoyment ($\beta_3$ = 2.388; t = 2.328; p = 0.020) have a positive significant effect on performance in Mathematics. A hierarchical multiple regression models further showed that performance in English adds unique variance in predicting performance in Mathematics above and beyond that which is predicted by the attitude constructs ($\Delta R^2$ = 0.316; $\Delta F$ = 323.275; Sig $\Delta F$ = <0.0001).


**Key words**: Attitudes, Confidence, Enjoyment; Mathematics, Regression Analysis

## Introduction

A negative attitude towards mathematics can be a disease which if not controlled becomes contagious to the learners. Sam (2002) claimed that, many students are scared of mathematics and feel powerless in the presence of mathematical ideas. Ernest (1996), learners regards mathematics as "difficult", cold, abstract and in many cultures, largely masculine. Learners are easily influenced by others and adopt a negative attitude and it becomes a major problem when the majority are underperforming due to the same factor. Hannula (2006), pointed out that a mathematics learner's liking or disliking of mathematics is derived from his/her belief structure. He further added that, people's beliefs and attitude towards mathematics are shaped by individual personal characteristics and experience related to their academic self-image. Nicolaidou and Philippou (2004), discovered that, learners who do well in Mathematics are those who are well motivated with a positive attitude and a high self-confidence towards the subject. They further postulate that, attitudes towards Mathematics and self-efficacy are the predictors of performance. If the learners believe and have an interest in the subject, they will not struggle to tackle anything concerning that subject. Mutodi (2014) found a strong positive correlation between performance and perception constructs such as self-confidence and interests in mathematics. Sinyosi (2015) suggest that, learners' self-confidence and positive self-esteem is developed by participation in supervised extra mathematics lessons and extra-mural activities.

According to the South African Department of Basic Education (2014), the higher rates of poor performance in all the learning areas is much contributed by the provinces that are underdeveloped e.g. Limpopo Province and the Eastern Cape. The rural setting of the school has got an impact towards confidence, enjoyment and performance in mathematics compared to the urban settings. Nkambule, et al (2011) states that despite several interventions, education in rural areas continues to face a set of challenges owing to, among other factors, the diverse geographic location of the schools, diverse learners' background and diverse learning styles.

Some interesting arguments on why learners in rural areas are lagging behind in terms of performance in mathematics were noted by Sinyosi (2015). He asserts that, most of the rural areas in South Africa are behind in terms of the use of science and technology because the state intervention and assistance is directed to developing white scientists not black people residing in the rural areas. Another notion was that, in the rural areas, parents contributes in changing the attitude of learners towards learning especially the subject of mathematics. Saritas, et al (2009), students' achievement is highly correlated with the educational attainment of parents. Sinyosi (2015), education attainment of parents serves as an indicator of attitudes and values which parents use to create a good environment promoting increased learning desire among children while in calculating their desire for achievement on the other hand. Parents act as role models, guiding and encouraging their children to pursue high educational goals and desires, Sinyosi (2015). Therefore, a positive attitude of learners towards mathematics starts from their background that is their parental involvement and guidance.

## Performance and Attitudes towards Mathematics

Gender difference influences the attitude in mathematics with boys out-performing girls according to (Knahwa 2012, Ochwo 2013). Other studies show that, girls have more anxiety when learning mathematics (Hyde, Fennema, Ryan, Frost & Hopp 1990; Karim & Venkatesan 2009; Opolet-Okumt, 2005). Girls in the rural school setting performs less compared to boys in the same school setting (Tapia, 2004). There are many factors which distracts learning of most of the girls in the rural areas, such as, the responsibilities of housing chores, early pregnancies, absenteeism due to effects of shortage of sanitary products etc. In the South African context, according to Moyana (1996), there is still an existing and disturbing sex difference in mathematics learning and achievement. Moyana (1996) noted that, there is low representation of women in scientific and technological fields, less number of women studying mathematics and available statistics showed a general male superiority in mathematics achievements. In many of the rural areas, girls face a number of challenges affecting their learning of mathematics in South Africa. Girls' education is very essential and there is a saying that says, "When you educate a woman you educate the world". Alabi (2014) asserts that, education prepares a person especially a girl-child, to fit properly into the web of social interaction and equally enhance the best performance in the social roles. Alabi (2014) noted some of the challenges in the Nigerian context and they are similar compared to the South African situation. Both the two countries are developing and they face same problems in the rural areas. Alabi (2014) postulated that, there is always injustice against the girl child in most parts of the world especially in Africa and Asian countries. According to his assertion, there is female feticide, female infanticide, sexual abuse, marginalization in terms of nutrition, health care, education, violence against women and early pregnancies.

### English as a medium of instruction

English has some significant effect on learning and also on the attitude of learners towards Mathematics. Learners' interpretation of mathematics concepts determines their understanding and eventually their performance. Cocking & Mestre (2004), as cited in Tsanwani (2009) discussed that mother tongue is very important to the clear formulation of mathematical concepts as all ideas are communicated between the teacher and the learner, either through oral or written materials. Tsanwani (2008) was studying about how English as a language affect performance in mathematics especially in disadvantaged learners. He further cited Orton (1992: 141) when he postulated that; "Communicating mathematical ideas so that the message is adequately understood is difficult enough when the teacher and learner have a common first language, but the problem is more acute when the preferred language differ." Most learners prefer to be taught in their vernacular because they understand it better whilst some teachers feel comfortable teaching using the English language. The problem usually surfaces when it comes to interpretation of Mathematics concepts. When mathematics is presented in English; those learners who cannot articulate the language always suffer. According to the study done by Raja (2010) in Malaysia, students especially from the rural schools are believed to have problems in learning mathematics and science in English due to their lack of English proficiency. This affects the students' achievement grades in mathematics and science subjects, especially in the public exams.

### Study objectives

The general objective of the study was to evaluate the effect of confidence, enjoyment and performance in English on performance in mathematics. Also the study explored the extent to which performance in English add unique variance in predicting performance in mathematics above and beyond which is predicted by confidence and enjoyment among high school students.

## Methodology

**Participants:** The study was carried out in Idutywa town in the Eastern Cape province of South Africa. Two schools were selected; one school is located in an urban setting and the other in the rural areas. The one in an urban setting has most of the learners coming from middle and higher income families. The one located in the rural areas has majority of its learners coming from disadvantaged areas. The two schools provided a list with names, gender, grade and mid-year scores of all grades 10 to 12 students doing mathematics. We used a standard recruitment protocol to invite them to participate in the study. Using computer-generated number sequences, we randomly selected 500 learners such that the sample included equal numbers of male and female as well as equal number across the grades. Learners doing mathematics in grades 10 to 12 who had been randomly selected were eligible. Recruiters contacted the randomly selected learners to determine their eligibility, willingness, and availability to participate in the study.

**Ethical Consideration:** Before the study was carried out, letters to seek for the permission to do the research were drafted and sent to the Principals of the two schools. Learners were informed and they indicated their consent by voluntarily admitting to participate in the study. Parental consent was obtained for all learners below the age of 18.

**Data Collection and Measures:** The data collection instrument was a survey questionnaire adopted from a project conducted by Wong and Chen (2012). The instrument scored Cronbach's alpha coefficient greater than 0.75 for all the major constructs. The questionnaire was a 5-point scale, 1 (Strongly Disagree); 2 (Disagree); 3 (Neutral); 4 (Agree); 5 (Strongly Agree). The construction of this questionnaire was basically guided by the following theoretical ideas; the confidence scale covered learners' self-concept of the ability to do the mathematics and the enjoyment scale examined the degree to which students enjoyed studying mathematics. The learners took about 20 minutes to answer the questionnaire. The questionnaire also included a section for demographic features. Performance in mathematics and English were measured using the learners' mid-year marks. The questions were read aloud and clarified to the learners so as to avoid misunderstanding and omission of questions.

**Data Analysis:** SPSS version 23 and SAS 9.1 were used for analysis. A normality test for the regression models was done using the Q-Q plots for residuals. Accessing these plots we found out that the points of the expected against the observed cumulative probabilities were lying on the line, hence the normality assumption for linear regression modelling was satisfied. Pearson's correlation coefficient was used for correlation analysis. Multicollinearity diagnosis was done for each model and the Durbin-Watson test was used to check for first order linear auto-correlation in our multiple linear regression data. All tests were carried out at 5% level of significance. To examine how the individual attitude towards mathematics constructs and performance in English affects the prediction of performance in mathematics, multiple regression models were used. The predicting variables, confidence, enjoyment, usefulness and performance in English were added to the model. To select a good model, stepwise regression was implemented. It is a semi-automated process of building a model successively adding or removing variables based solely on the t-statistics of their estimated coefficients. Hierarchical regression was also used to see the effect of adding performance in English to attitude in the prediction of performance in mathematics.

### Results

### The demographic profile of the respondents

A descriptive approach was used to describe the demographic variables of the study (see Table 1 below). The study was carried out from population size of 500 learners from two schools with each school contributing 250 learners. The majority of the respondents (51.8 %, n = 259) are females while male respondents comprised 48.2% of the study sample (n = 241). From the information in the table, the number of learners from grade 10 is 210 contributing 42.0% of the respondents and they were the majority of the total sample space. The grade 11 learners are 140 making 28.0% of the respondents. The grade 12 learners comprised 30.0% (n = 150) of the respondents. The average age of the respondents is 18 years.

## Table 1: Descriptive Statistics for Biographical Variables

| Variable | Levels | | f | Valid % |
|---|---|---|---|---|
| Schools | Urban | | 250 | 50 |
| | Rural | | 250 | 50 |
| Classes/Grades | 10 | | 210 | 42 |
| | 11 | | 140 | 28 |
| | 12 | | 150 | 30 |
| Gender | Male | | 241 | 48.2 |
| | Female | | 259 | 51.8 |
| | | | | |
| Age | 12 – 15 years | | 43 | 9 |
| | 16 – 19 years | | 375 | 75 |
| | 20 – 23 years | | 79 | 16 |
| | > 24 years | | 3 | 1 |

## Mean Comparisons of Demographic Features by the Major Study Constructs

Table 2 below depicts an independent-samples test which compared the means between male and female student's levels on the attitudes and performance variables. Levene's test for homogeneity of variance (homoscedasticity) was used. This test verified that the assumption of equal variances holds in all samples. Significant differences in means between males and females were only noticed on confidence and performance in English. Males (mean = 3.3838; SD = 0.78560) showed a significantly higher mean level of confidence than their female (mean = 3.1824; SD = 0.72220) counterparts (t = 2.986; df = 498; Pr > |t| = 0.003). This shows that male students had higher mean levels of confidence than male students. However, females (mean = 49.7104; SD = 19.33740) showed a significantly higher mean level of English marks than their male (mean = 44.0788; SD = 19.11320) counterparts (t = -3.272; df = 498; Pr > |t| = 0.001). Thus females perform significantly better in English than males.

## Table 2: T-Tests for Mean Gender Differences on Study Variables

| Study Variable | Gender | Mean | SD | Levene's Test for Equality of Vari- | | T-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| Confidence | Male | 3.3838 | 0.78560 | 2.448 | 0.118 | 2.986 | 498 | 0.003** | 0.20138 | 0.06743 |
| | Female | 3.1824 | 0.72220 | | | | | | | |
| Enjoyment | Male | 3.7260 | 0.68852 | 1.028 | 0.311 | 0.659 | 496 | 0.510 | 0.04193 | 0.06360 |
| | Female | 3.6841 | 0.72780 | | | | | | | |
| Maths | Male | 38.2449 | 20.68258 | 1.214 | 0.271 | -0.565 | 498 | 0.572 | -1.05248 | 1.86126 |
| | Female | 39.2973 | 20.90103 | | | | | | | |
| English | Male | 44.0788 | 19.11320 | 0.005 | 0.942 | -3.272 | 498 | 0.001** | -5.63159 | 1.72107 |
| | Female | 49.7104 | 19.33740 | | | | | | | |

**Significant differences with equal variances assumed
*Significant differences with equal variances not assumed

We also carried a comparison of the means of the major study constructs between the two selected schools. Table 3 below shows an independent-samples test which compared the means between the two schools on the attitudes' constructs and performance variables. Levene's test for homogeneity of variance (homoscedasticity) was used. This test verified that the assumption of equal variances holds in comparisons of enjoyment and performance in English. As for, confidence and performance in mathematics equality of variances were not assumed. Significant differences were noticed on all study variables. The urban school showed a significantly higher mean level for all the variables. This shows that the urban school had significant higher mean levels on confidence (t = 4.486; df = 489.6; Pr > |t| = 0.001), enjoyment (t = 4.488; df = 496; Pr > |t| = 0.001), performance in mathematics (t = 22.200; df = 449.0; Pr > |t| = 0.001) and performance in English (t = 23.795; df = 498; Pr > |t| = 0.001) than the rural school.

**Table 3: T-Tests for Mean School Setting Differences on Study Variables**

| Study Variable | Setting | Mean | SD | Levene's Test for Equality of Vari- | | t-test for Equality of Means | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
| **Confidence** | Urban | 3.4290 | 0.79260 | 5.498 | 0.019 | 4.486 | 489.6 | 0.000* | 0.29900 | 0.06666 |
| | Rural | 3.1300 | 0.69464 | | | | | | | |
| **Enjoyment** | Urban | 3.8448 | 0.65786 | 1.744 | 0.187 | 4.488 | 496 | 0.000** | 0.27976 | 0.06233 |
| | Rural | 3.5650 | 0.73086 | | | | | | | |
| **Maths** | Urban | 53.4320 | 17.01043 | 21.978 | 0.000 | 22.200 | 449.0 | 0.000* | 29.28400 | 1.31910 |
| | Rural | 24.1480 | 12.06867 | | | | | | | |
| **English** | Urban | 61.1440 | 13.89733 | 1.348 | 0.246 | 23.795 | 498 | 0.000** | 28.29600 | 1.18915 |
| | Rural | 32.8480 | 12.66438 | | | | | | | |

**Significant differences with equal variances assumed

*Significant differences with equal variances not assumed

## Correlation Analysis of Theoretical Constructs

Pearson correlation analysis gave preparatory decomposition into the study variables. Table 4 illustrates the variables presented in the study. All the variables were significantly correlated to performance in mathematics. Thus, performance in mathematics was significantly moderately positively correlated to confidence (r = 0.390; p = <0.0001); enjoyment (r = 0.327; p = <0.0001), and with performance in English (r = 0.664; p = <0.0001).

**Table 4: Pearson product-moment correlations (r) and significance probabilities (p) for relations of performance in mathematics to theoretical constructs**

| | Theoretical Constructs | r | *p* |
|---|---|---|---|
| **Attitude** | | | |
| 1 | Confidence | 0.390 | <0.0001** |
| 2 | Enjoyment | 0.327 | <0.0001** |
| **Performance** | | | |
| 1 | English | 0.664 | <0.0001** |

** Correlation is remarkable when the significant level is 0.01(Two-tailed test).

## Regression of attitudes and performance in English on performance in Mathematics

The stepwise procedure yeilded a total of three significant models. Table 5 below shows that the first significant model was the one with performance in English as a predictor variable on performance in Mathematics (F = 391.826; df = 1; p = <0.0001). The standardized β coefficients in Table 6, shows that performance in English has a significant positive effect on performance in Mathematics ($\beta_1 = 0.717$; t = 19.795; p = <0.0001). Multicollinearity is non-existent in this linear regression model as tolerance was > 0.1 (and VIF < 10) for the significant variable (performance in English). The resulting unstandardized model yields;

*Performance in Mathematics = 5.166 + 0.717* Performance in English + residual €*

The second significant variable that was added to the model was confidence which yielded a significant model (F = 72.579; df = 2; p = <0.0001). The collinearity diagnostics in Table 6 shows that multicollinearity does not exist in this $2^{nd}$ regression model (Tol > 0.1 (or VIF < 10 for all variables). Parameter estimates show that both performance in english and confidence have significant positive effect on performance in Mathematics, and the standardized regression coefficients are $\beta_1 = 0.660$ (p = <0.0001) and $\beta_2 = 7.469$ (p = <0.0001) respectively. Thus, we can get the standardized regression equation of performance in Mathematics:

*Performance in Mathematics = -16.63 + 0.660* Performance in English + 7.469*Confidence + residual €*

Enjoyment was the last significant variable to be added to the regression model. This yielded a significant linear regression model (F = 177.091; p = <0.0001). Durbin-Watson test for auto-correlation (d = 1.564) is between the two critical values of 1.5 < d < 2.5 and therefore we can assume that there is no first order linear auto-correlation in our multiple linear regression data. In table 5, the variance inflation factor (VIF) of each independent variable is between 0.804 and 1.244. According to the standard of statistical test, variance inflation factor (VIF) less than 10 and tolerance greater than 0.1 indicated that collinearity problem does not exist among variables. Thus in the regression model collinearity problem does not exist among variables. The parameter estimates in Table 6 shows that all the predictor variables, performance in English ($\beta_1 = 0.645$; t = 18.444; p = <0.0001), confidence ($\beta_2 = 6.631$; t = 7.024; p = <0.0001) and enjoyment ($\beta_3 = 2.388$; t = 2.328; p = 0.020) have a positive significant effect on performance in Mathematics. The resulting final unstandardized model yields;

*Performance in Mathematics = -22.03 + 0.645* Performance in English + 6.631*Confidence + 2.388*Enjoyment + residual (e)*

**Table 5: Model Summary**

| Model | R-Square Statistics | | | df 1 | df 2 | Δ F Statistics | |
|---|---|---|---|---|---|---|---|
| | R-Square | Adjusted R-Square | Δ $R^2$ | | | Δ F | Sig Δ F |
| 1 | 0.442[a] | 0.441 | 0.442 | 1 | 494 | 391.82 | <.0001 |
| 2 | 0.514[b] | 0.512 | 0.072 | 1 | 493 | 72.579 | <.0001 |
| 3 | 0.519[c] | 0.516 | 0.005 | 1 | 492 | 5.421 | 0.020** |

**Significant change in amount of variation of dependent variable being explained by the predictors.
a. Predictors: (Constant), Performance in English
b. Predictors: (Constant), Performance in English, Confidence
c. Predictors: (Constant), Performance in English, Confidence, Enjoyment
Dependent Variable: Performance in Mathematics

**Table 6: Parameter Estimates**

| Model/Parameter | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|
| | B | Std. Error | Beta | | | Tol | VIF |
| **1** (Constant) | 5.166 | 1.839 | | 2.809 | .005* | | |
| Performance in English | 0.717 | 0.036 | 0.665 | 19.795 | .000* | 1.000 | 1.000 |
| **2** (Constant) | -16.63 | 3.082 | | -5.395 | .000* | | |
| Performance in English | 0.660 | 0.035 | 0.612 | 19.109 | .000* | 0.962 | 1.040 |
| Confidence | 7.469 | 0.877 | 0.273 | 8.519 | .000* | 0.962 | 1.040 |
| **3** (Constant) | -22.03 | 3.848 | | -5.726 | .000* | | |
| Performance in English | 0.645 | 0.035 | 0.598 | 18.444 | .000* | 0.930 | 1.076 |
| Confidence | 6.631 | 0.944 | 0.242 | 7.024 | .000* | 0.822 | 1.216 |
| Enjoyment | 2.388 | 1.026 | 0.081 | 2.328 | .020* | 0.804 | 1.244 |

Note; Dependent Variable: Performance in Mathematics
*Significant effect.

**Hierarchical Multiple Regression Analyses**

To examine if performance in English add unique variance in predicting performance in mathematics above and beyond that which is predicted by the four attitude constructs, a hierarchical multiple regression model was used. The predicting variables, confidence and enjoyment were added to the model first and then performance English. The $R^2$ change was noted. A hypothesis test using the F-test was done to test whether the change in $R^2$ is significant after addition of each of performance in English to the constructs of attitude

## Table 7: Summary of hierarchical multiple regression analyses testing attitude constructs and performance in English in the prediction of performance in mathematics

| Variable | Performance in Mathematics | | | | | |
|---|---|---|---|---|---|---|
| | *F* | *FD* | *$R^2$* | *$R^2D$* | *df2* | *Sig. FD* |
| [a]Attitude Constructs | 31.599 | | 0.205 | 0.205 | 491 | <0.0001* |
| [b]Performance in English | | 323.275 | 0.521 | 0.316 | 490 | <0.0001* |

*Significant change in amount of variation of dependent variable being explained by the predictors.

a. Predictors: (Constant), Confidence, Enjoyment,

b. Predictors: (Constant), Confidence, Enjoyment, and performance in english

Table 7 above shows that attitude torwards mathematics explains 20.5% of the variation in the dependent variable (R-Square = 0.205). Combined with performance in English, the resultant model accounted for a total of 31.6% of the variation in performance in mathematics. Thus this model adds significant variation to the first model. This means adding performance in English to attitude torwards mathematics as independent variables on performance in mathematics results in a significant increase in the amount of variation explained by the model ($\Delta R^2 = 0.316$; $\Delta F = 323.275$; Sig $\Delta F = <0.0001$).

## Discussion

From this study it has been found out that learners who perform very well in mathematics have high self-confidence and enjoy the study of the subject. In this study, confidence as a factor does have a significant effect on the performance of mathematics. The result is supported by findings from study which was carried out by Mutodi (2014) concerning the influence of students' perceptions on mathematics performance. There is also a profound effect of the English language as a medium of instruction compared to learners studying in a town school. Learners in the rural areas struggle to articulate and assimilate concepts of mathematics since they are always presented in English. Learners who are good in English can understand mathematics concepts better. This result is supported by Howie (2007), from the study carried out in South Africa about the effect of language and factors affecting secondary students' performance in mathematics. The author's findings reviewed that, pupil's proficiency of English was a strong predictor of their success in Mathematics.

The study has helped in shedding light on which students' exhibit higher motivation in mathematics. Our findings agree with previous research on how enjoyment is an important factor in performance in mathematics (Balentyne, & Varga, 2017; Herges, Duffied, Martin, & Wageman, 2017). In light of this leaners who find mathematics enjoyable and are confident increases their prospects of success. Our findings align to the link between academic abilities and confidence identified by Bandura, (1993). In adopting our findings researchers must be mindful of the context and environment in which the study was conducted. Findings extend on the role of the English language on how it aids leaner in an urban environment is more exposed and more exposed to it thus more confident and performs better.

## Recommendations

Learners' attitude can be changed by transforming the way they perceive mathematics. We can do that by introducing a method of teaching that is accommodating to the learners. Teaching and learning must be learner centred. In order to boost confidence and enjoyment of mathematics, learners need to be sequentially motivated. Differences between the rural and urban schools go beyond the instructor. Policy makers must play a key role as a lot of investment is required especially in the black dominated environments in which the study was conducted. Embracing of technology can also improve the challenges identified.

Findings of the study are useful to stakeholders as we seek to find meaningful ways of making mathematics acceptable by all and keep learners engaged through addressing the identified gender and school setting disparities. More resources should be channelled towards the girl child so as to boost their confidence in doing mathematics. Rural schools should initiate measures and interventions for learners to have more confidence and enjoyment in doing mathematics. There is need for teachers, parents, and any other education stake holder to enhance positive attitudes towards mathematics through encouraging both female and male learners as well as rural and urban learners to equally embrace mathematics.

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# Change of Landscape – Opportunities for Access to Science, Engineering and Technology through Robotics, Mentorship and Social Media

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3Inspired towards Science, Engineering and Technology Community Engagement (I-SET) Flagship Project, College of Science, Engineering and Technology, University of South Africa

**Abstract –** *The Inspired towards Science, Engineering and Technology (I-SET) is a community engagement project of the College of Science, Engineering and Technology (CSET) at the University of South Africa (Unisa). The aim of this project is to inspire and create access to Science, Engineering and Technology through robotics, mentoring and social media. Robotics introduces the engineering fundamentals and programming principles, and also develops 21st century skills (problem solving, critical thinking, and collaborative learning). Mentoring is accomplished through community engagement and outreach, by learners, students, educators, academics and community leaders. Social media provides the opportunities for robotics teams of learners to communicate, collaborate, share content and compete. We are introducing a new robotics competition that avoids the challenges of distance and the costs to travel and allows teams to meet other teams locally, nationally and internationally through the use of digital media. This paper proposes an envisaged way forward to allow more learners access to inspired science, engineering and technology thorough robotics.*

**Keywords:** robotics, STEMI, community engagement

## 1 Introduction

The Inspired towards Science, Engineering and Technology (I-SET) is a community engagement project of the College of Science, Engineering and Technology (CSET) at the University of South Africa (Unisa). The main purpose of this community engagement project is to inspire, to create awareness and to provide access to Science, Engineering and Technology through the fun activities of robotics. Science, Technology, Engineering, Mathematics, and Innovation (STEMI) are presented to learners and students through community engagement and outreach, by mentors including students, educators, academics and community leaders. However, not all learners have access to robotics due to the constraints of location, distance, time and costs incurred. This paper presents opportunities proposed within the I-SET project, some in collaboration with Texas Tech University (TTU), to overcome these constraints so as to ensure access for a growing community of learners and mentor, thereby changing the landscape for inspired science, engineering and technology.

### 1.1 Robotics

The learners use the MindStorms EV3 or NXT kit to build robots, and transform robotics. Through robotics, learners are introduced to the fundamentals of engineering (including the concepts of friction, traction, centre of gravity, axles and pulleys) when building the robot, and grapple with the principles and concepts of programming (including repetition loops, decision-making switches, variables, constants, and data) to ensure that the robot can be programmed to successfully accomplish a specific task. However, during these robotics sessions, teams of learners implicitly learn and develop 21st century skills, including but not limited to problem solving, critical thinking, and collaborative learning.

### 1.2 Mentorship

Mentoring in robotics within the I-SET project is accomplished through community engagement and outreach, by learners, students, educators, academics and community leaders. Mentorship refers to the passing on of knowledge and skills from one person to another, from more experienced to less experienced. This mentorship, however, usually pertains to a specific area of expertise. Mentorship can refer to any interaction where such knowledge or skills are passed on. It is highlighted that there exists a lack of university-based service-learning mentoring programmes [1].

### 1.3 Social media

Social media are internet applications that allow for a virtual community of social media users to co-create and sharing of content, and to collaborate and communicate between members of a virtual community [2]. Thus, the use of social media can be considered a tool to overcome the challenges of distance, location and costs.

### 1.4 Current robotics landscape

The landscape may be viewed from a number of perspectives – and what you see may depend on your distance from and focus on the issues. You could also choose to close your eyes to ignore the landscape (perhaps only for a while) – but then you may miss the inspired changes that are about to happen!

**Our landscape as learners inspired to learn:** The learners that attend I-SET robotics workshops are keen and eager to build and program. The noise levels of excitement during a workshop, the reluctance to leave an ended workshop, and the eagerness to inquire when the next workshop starts all bear testimony to a cohort of learners that want to learn. For some learners, there is only ever one opportunity to build and program a robot. A very small number of learners in South Africa are given the opportunity to be coached and mentored in robotics within the school environment, i.e. within the curriculum or as an extra-mural activity of the school.

**Our landscape of mentors and coaches:** The educators and community leaders (the potential coaches and mentors of teams) are intimidated by the prospect of teaching engineering and programming. There are very few educators and community leaders dedicated to make a difference for a team of learners. The lack of support and equipping of coaches and mentors is being addressed by I-SET.

**Our landscape of students:** The students in the sciences and engineering have limited exposure to practical applications of science, engineering and technology, as well as the needs of the learners. Graduateness should include an awareness of the needs of science, engineering and technology. Opportunities are required for a play-it-forward SET model, for the mutual benefit of all student and learner scientists, engineers and technologist involved.

**Our landscape in recognition for our youth of Science, Engineering and Technology:** when a team does qualify as National Champion in a robotics competition, there is zero support for the team to proudly represent South Africa and Africa at an international event.

**Our landscape in a world perspective:** In the world there are about 25,000 teams of learners that participate annually in the For Inspiration and Recognition of Science, Engineering and Technology (FIRST) Lego League (FLL) robotics competition. The entire African continent does not have 250 teams (i.e. not even 1%).

In section 2 of this paper, the concepts of robotics, mentorship and social media are considered in a literature review, specifically with reference to the creation of access to and opportunities in robotics. Section 3 elaborates on the I-SET initiative within the current robotics landscape. Section 4 considers proposed initiatives to address the challenges experienced in the current landscape, within suggestions and recommendations to change the landscape. Section 5 concludes with a visionary landscape of inspired science, engineering and technology, and presents recommendations for future I-SET initiatives to address the changing of a landscape to inspire science, engineering and technology.

## 2 Literature

To change the landscape, the current landscape needs to be understood. Tools, techniques and initiatives that may be used to change the landscape must be identified. Currently, robotics is presented as an opportunity to inspire the learning of Science, Engineering and Technology, mentorship refers to the engaged sharing of skills and knowledge, and social media is a tool that may be used to alleviate some of the challenges that hinder sustainable access to robotics for a growing community of learners. It is these three factors that are considered the focus of this paper.

### 2.1 Robotics

Robotics may be used to teach and to learn the fundamentals of engineering (e.g. friction and traction, centre of gravity and weight distribution, axles, wheels, pulleys, gears, power and transmission, rolling resistance, backlash, and mechanical efficiency) for the building of a robot for a specific function. However, the robot also needs to complete tasks. To do this, the principles of programming are required to program the robot (e.g. repetition and loops, decision-making and switches, constants, variables, stored procedures). These robots can then compete in robotics competitions [4][3].

The presentation of robotics for the inspiration of Science, Engineering and Technology may take on a range of options. The robotics classes are usually presented by educators as an extra-mural activity at schools or by community leaders as a community activity in communities.

Robotics teams are encouraged to represent the school at competitions, although many other alternatives such as robotics themes, art and engineering combinations, story-telling and exhibitions have also been proposed as entry points into robotics [5].

### 2.2 Mentorship in Science, Engineering Technology and Robotics

The mentorship of Science, Technology, Engineering and Mathematics (STEM) is considered vital for inspiring learners and students in the learning of Science, Engineering and Technology. For the promotion of mentoring in robotics, the For Inspiration and Recognition of Science and Technology (FIRST) Lego League (FLL) promotes the concept of team work, where each team has at least one coach/ mentor. Both a coach and a mentor are recommended. FIRST have a collection of guides and online resources available for the coaching and or mentoring of these robotics teams. There are also guidelines for effective mentoring. However, the learners are not only mentored in the robotics aspects per se (i.e. engineering and programming). Participation in a robotics competition requires that the learners (of up to ten learners in a group) also collaborate as a team. This encourages core values, communication and participation. The FLL robotics competition also requires that the learners grapple with a real world issue (e.g. food contamination, old people, the new ways of learning and dealing with trash) according to the annual research theme of the competition, and are required to research and present their team solution. This encourages the so-called 21st century skills including problem-solving skills, innovative thinking and changing perceptions of the world.

The options for mentorship in the presentation of robotics and participation in robotics competitions thus spans a range of skills and knowledge related to Science, Engineering and Technology, as well as the identified 21st century skills of problem-solving, innovation, critical thinking and collaboration.

Students, however, can also be mentored in robotics by academics as part of undergraduate course work. REF. Academics can also mentor educators in robotics as part of community engagement and outreach.

### 2.3 Social media

Opportunities in the use of social media to ensure access to science, engineering and technology exist. A plethora of social media (websites, online tutorials, YouTube videos, Vimeo, FaceBook) and digital resources exist to support the furtherance of science, engineering and technology through robotics.

**Tutorials online**: these are usually presented by the learners in teams to explain a concept (engineering or programming) in terms that fellow learners can grasp. The quality and relevance of the tutorials vary. These tutorials may be once off tutorials, or a series covering an aspect of robotics. There are professional tutorial presented by universities, NPOs and businesses, and there are also tutorials presented by young learners with an enthusiasm to inspire.

**YouTube videos of robotics competitions (FLL, WRO)**: Teams are very eager to share their accomplishments (albeit just a segment of a mission challenge). This is specifically true for high scoring teams, who are eager to assist and guide newer teams.

• **Communities of learning:** There exist virtual groups that maintain and develop an ongoing collection of resources. To facilitate communication, there is an option to subscribe to email listings.

• **Facebook:** Teams are encouraged to collaborate and share information, especially to encourage newer teams, graciously! Teams usually invite other teams as friends, and are quick to post any exciting news (with pictures!).

• **Research papers:** There are a number of research papers pertaining to ongoing research and anecdotal evidence of the benefits of teaching of robotics, to learners at school and students at university.

## 3 I-SET Initiatives within the current robotics landscape

The goal of the I-SET project is to inspire and create awareness of Science, Engineering and Technology for students, learners, educators and community leaders. This community engagement project has both an outreach and an engagement focus to ensure that this goal is attained. However, the constraints of volunteerism of academics, and of logistics of time and distance, have necessitated that the I-SET team consider alternative deployment options. These mentorship aspects are identified and discussed in terms of the youth involved in this project.

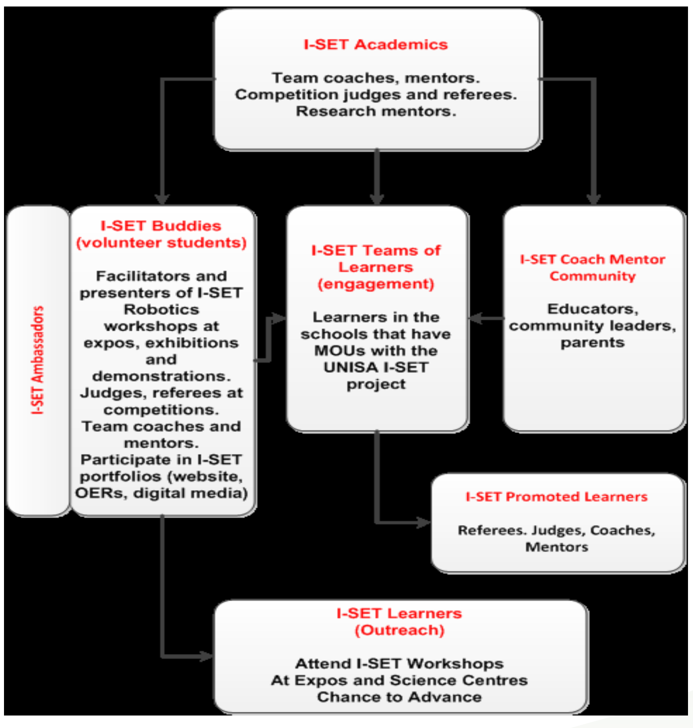


Figure 1: I-SET Mentoring in Science, Engineering and Technology

## 3.1 I-SET Learners (Teams and Workshops)

The academics mentor these teams of learners at schools that have partnered with the I-SET project. The school is required to have a memorandum of understanding in place for the I-SET project to engage with the learners. The learners attend robotics sessions as an extra-mural activity after school on a given day.

Learners, too old to participate in the competition, are encouraged to participate in the I-SET project by volunteering as coach mentors to younger and beginner teams, and also by volunteering as competition judges and referees. Thus experiences of mentorship from coaches, mentors and educators are used for the development of the next generation of I-SET teams of learners.

To create awareness of robotics for learners in schools where robotics is not presented, I-SET also presents robotics workshops at Science Expos throughout South Africa. UNISA students volunteer as I-SET Buddies and are trained in robotics to facilitate and present these workshops to learners. The I-SET robotics workshop, usually two hours long, includes the building of a basic robot (brick, two motors and a sensor) and the introductory programming required (move, loop and switch with sensor input). The learners are mentored by the I-SET Buddies and Ambassadors. These workshops are usually presented to groups of up to 30 learners. In the South African context this Buddy mentoring has greater relevance, as the learners are presented with robotics (Science, Engineering and Technology) in their own language and by people they can relate to and see as a role model. Robotics provides an opportunity for a practical presentation of a theoretical concept. At the end of the workshop, each participating learner is presented with an I-SET certificate as evidence of a successful robot building and programming session (i.e. a mentoring session in Science, Engineering and Technology).

It is envisaged that through this awareness of Science, Engineering and Technology, the educators may volunteer to present robotics at the school, develop a school robotics team of learners, and also be part of the I-SET project.

### 3.2 I-SET Coaches and Mentors

The academics of CSET participate in the I-SET project in a range of roles and portfolios. The responsibilities within the I-SET project may include volunteering as a team coach and/ or mentor, as a competition judge and referee, or a research mentor. For an I-SET team coach mentor, through regular mentor coach sessions, academics guide the understanding of the learners though engineering fundamentals, programming principles and research skills. The academics mentor the educators and community leaders of the I-SET teams.

However, to address the greater need for mentorship in order to increase the number of teams, a UNISA short learning program (SLP) has been launched.

The SLP, I-SET Robotics, has four courses defined, namely: Practical Experience of Engineering & Programming, Components & Pedagogy, Problem Solving, Data & Debugging, and Sensors & Programming. Each semester course of 15 weeks is online. No prior robotics experience is required initially. However, the first two courses are suggested as a pre-requisite for the latter two. The content of the SLP is enhanced by lessons learnt within the community of coaches and mentors, and is used to equip and support a new recruitment of coaches and mentors.

### 3.3 I-SET Buddies and Ambassadors (students)

Each year the I-SET project is invited to present robotics workshops at science exhibitions, regionally and nationally. To meet these commitments, a call was made in 2012 for Unisa student volunteers for the I-SET project. Only 30 of the 480 applicants could be selected for robotics mentorship and training. These students, known as I-SET Buddies, were recruited to facilitate I-SET workshops. They attend regular training, write reports and also to contribute to the strategic development of I-SET project.

The I-SET Buddies are provided with opportunities to travel to expos to facilitate I-SET workshops. Through these workshops, learners are mentored by Unisa students and given an opportunity to build and program at least one robot. The I-SET Buddy is required to eventually develop and present I-SET Robotics workshops.

The graduating I-SET Buddies have been mentored on social responsibility and opportunities to encourage Science, Engineering and Technology. Thus, the graduateness of these students is enhanced through the mentorship.

The I-SET Buddies are also required to volunteer at robotics competitions as judges, referees or in a competition administration capacity at regional and national competitions. I-SET Buddies have also coached and mentored teams of learners participating in the competitions. I-SET has recruited a new cohort of I-SET Buddies in January 2017. Training has commenced.

After two years as I-SET Buddies, these Unisa students are equipped to develop and to present I-SET robotics workshops. These students are then promoted to I-SET Ambassadors. These I-SET Ambassadors will, in turn, mentor the next recruitment of I-SET Buddies. It is envisaged that this title will provide life-long “membership” to the I-SET project.

## 4 I-SET to Change the Landscape

The following initiatives have been promoted to ensure that a greater community of learners have access to robotics,:

### 4.1 Practical Experience of Engineering and Programming

To increase the number of equipped coaches and mentors, a more practical perspective was required. This SLP was also developed to address the needs of mentors and coaches to understand the requirements for coaching and mentoring a team, and also to prepare a team for a robotics competition. This online course has weekly assignments to encourage mentor and learner participation, and includes a 6 week mini-virtual robotics competition. The final assignment is the showcasing of the achievements to the community.

## 4.2 Virtual GEAR Robotics Competition

To increase the number of learners, teams can now participate in a robotics competition in their classroom. This is a virtual competition in collaboration with Texas Tech University. The concept of a virtual competition was explored in collaboration in 2015. The teams reside in other countries (e.g. Germany, USA and South Africa). This competition only requires building and programming a robot, and the completion of an Engineering book. The challenge mat consists of items from a hardware store. The competition encourages entry level teams to start. There are two categories of teams; the first-timers are teams that have never competed in a robotics competition before, whilst the global stream allows for teams to form alliances and compete with international teams.

### 4.3 I-SET Robotics Hub

The I-SET project has been allocated a venue in which to host robotics hub. This opportunity gives the project a home for the EV3 robotics kits, challenge sets and laptops.

### 4.4 Science Centre robotics

To increase the number of learners that have access to robotics, it is envisaged to develop robotics teams at Science Centres nationwide.

A three-day training workshop was presented to facilitators of these Science Centres.

### 4.5 I-SET Buddies (2017)

To increase the number of volunteer coaches and mentors to facilitate the I-SET workshops, I-SET sent out a call for the 2017 intake of I-SET Buddies. These students are no longer limited to the proximity of the UNISA Science Campus. Students receive their training material online (or can attend training sessions). For students that do not have robotics kits, an initiative has been launched to make robotics kits available at UNISA libraries at all UNISA regional offices.

### 4.6 I-SET Coach Mentor Community

The I-SET Coach Mentors are in communication with each other via a closed Facebook group. They also share a Google Drive of teaching and learning resources. It is envisaged that this collection of resource will grow through ongoing collaborative co-creation.

## 5 Recommendations and Conclusions

The I-SET outreach measurable target is the number of learners who have the opportunity to build and program at least one robot. The I-SET engagement measurable target is the number of schools that have at least one robotics team participating in at least one regional robotics competition. The African saying refers to the fact that it takes a community to raise a child. This paper concludes with the comment that perhaps, in this 21st century, it may take opportunities of community engagement in STEMI (engaging and mentoring) to change the inspired STEMI robotics landscape for all children of South Africa.

## 6 Acknowledgements

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# Promoting Mathematics and Science competitions: A district initiative

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*This paper focuses on a district initiative to promote Mathematics and Science competitions among schools from disadvantaged areas. These schools were identified by their involvement in projects promoted by the district, province or outside organisations (in collaboration with the district). 10 schools were invited to be a part of the initiative. This initiative consisted of activities which took place in two sessions. The first session consisted of a Natural Sciences Olympiad for grade 8 & 9 learners and Mathematics Relays for grade 10 & 11 learners. The second session consisted of a Science Olympiad (incorporating both Physical Sciences & Life Sciences) for grade 10 & 11 learners and Mathematics Relays for grade 8 & 9 learners. The learner participants appeared to be the top learners of the schools. They completed questionnaires after their activities and provided rich data for this paper. Learners stated that they were honoured to represent their schools in the district competition and made their parents and other well- wishers proud of them. All learners indicated an affinity for Mathematics and the Sciences and appeared to look in these directions for their future careers. Top schools and learners received prizes at the awards function. The competition appears to have paid dividends for most of the schools since more learners have been encouraged to participate in National Mathematics and Science Olympiads in 2017.*

## Introduction

There are various Mathematics and Science competitions in South Africa. These competitions are used to promote the Mathematics and Sciences at schools. Although there have been great strides in getting learners from disadvantaged schools to participate in such competitions, more needs to be done to ensure that learners from these schools are given opportunities to participate and be successful in these competitions.

This paper focuses on a district initiative to promote Mathematics and Science competitions among schools from disadvantaged areas. These schools were identified by their involvement in projects promoted by the district/ province or outside organisations (in collaboration with the district). Before discussing this initiative further, it is important to examine some of the literature on Mathematics and Science competitions.

## Literature survey

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, 2017)

While the above mentioned benefits apply to Mathematics competitions, these may also apply to Science competitions. However, one of the key challenges is getting learners from schools in disadvantaged areas to participate in these competitions in big numbers.

Schools from advantaged areas have been involved in Olympiads for quite some time. Govender (2014a) listed the following key factors which contributed to the popularity of Mathematics Olympiads and competitions at some of these schools:

- The role of the teacher in being a driving force behind Mathematics Olympiads at the schools.
- The learning culture of the school in which participation in Mathematics Olympiads has become a "normal" school activity.
- The performance of learners in school mathematics is an important factor as usually the top learners tend to participate in Mathematics Olympiads.
- The involvement of learners in both individual and team events such as Mathematics relays.
- The involvement of parents in terms of encouraging their children to participate in these competitions and providing transport.

One of the inhibiting factors to promoting Mathematics and Science competitions at schools in disadvantaged areas is that teachers, generally, do not have experience in competitions and are not likely to show any enthusiasm for such competitions. This lack of exposure means that teachers may not have a frame of reference in respect of competitions and may not be in a position to encourage participation of their learners in such competitions. Thus, if this situation has to be changed then student teachers should be given the opportunity to do problem solving activities in both the Mathematics and Sciences as part of their training. This would also involve working through Olympiad papers.

Govender (2014b) reports on an initiative to develop pre-service Mathematics teachers' problem solving abilities. Only one out of 14 students in the group had taken part in a Mathematics Olympiad while at school. In line with the theories on experiential learning, these students would not have been able to pass on these experiences to their own learners. It was important to expose these students to Mathematics competitions so a structured intervention was initiated. The South African Mathematics Challenge was used as a vehicle to expose these students to problem solving in Mathematics. This intervention could be regarded as successful as the students became well-versed in problem-solving and using problem-solving strategies. It augured well for when they started teaching as they had some experience of competitions and with further development should be able to introduce problem solving activities to their own learners.

However, this tends to be more difficult with experienced practicing teachers. Govender (2015b) worked with primary school and high school Mathematics teachers to establish their problem solving capabilities and found that while these teachers are knowledgeable about problem solving and problem solving competitions such as Mathematics Olympiads, they tended to struggle with the problems in these competitions. It is possible that their own difficulty with the problems has made them reluctant to enter their learners for these competitions as they believed these competitions to be "difficult" and that their learners will not cope.

There have been initiatives to promote Science competitions among learners, especially from schools located in disadvantaged areas. A study by Taylor (2011) on the participation of township learners in the Science expo revealed the following:

- The learners conceptualised Expo as an opportunity for success with the notion of success conceptualised in different ways.
- However, their experience of Expo was the opposite of success: they saw themselves as losing, with this outcome attributed to a range of internal and external factors.
- These factors include limited access to resources or not having teachers who may support these kinds of activities.
- Further, some learners see no relation between their classroom science and their Expo projects and the time spent on the Expo projects could have been better spent on their classroom science and focussing on the grade 12 examinations. (Taylor, 2011)

It would appear that these learners, while being enthusiastic about the Expo and hopeful about success, had their enthusiasm tempered with the lack of success in the competition, believing that they should have spent their time with other activities rather than the Expo competition. This is rather unfortunate as the lack of success in competitions does not mean that they did not learn anything. At the same time, if learners are not supported for competitions by their teachers and others, then there is a likelihood of learners performing poorly and becoming negative about such competitions.

SAMF has started a programme to assist learners with preparation for the South African Mathematics Olympiad (SAMO). This programme, called the Siyanqoba Regional Olympiad training programme, has been designed with the following aims in mind:

- Motivate learners to improve their learning of mathematics and 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.

(SAMF, 2016)

The purpose of the Siyanqoba programme (in terms of impact) is to:

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

(SAMF, 2016)

There will be more about the Siyanqoba programme later in this paper. Another study which is relevant to this paper is by Jennifer Wirt (2011) of the USA. She analysed Science Olympiad participants' perceptions regarding their experience with the Science and Engineering competition and came up with the following recommendations for education districts in the USA:

- Districts should develop and encourage participation in Science Olympiad and support students and teachers who are interested in starting Science Olympiad teams or who are already involved in the organization.
- Districts should use this research and other research on Science Olympiad to determine which of the components they can put in place in their schools to positively impact regular classroom instruction.
- Several participants spoke about liking the chance to learn in a way that did not involve solely studying from a textbook. They felt that they got real experience in the fields of science and engineering and that it was more significant then what was happening in their classrooms. Thus, the regular classroom is obviously not fulfilling the needs of those students who are intensely interested in science and engineering.
- Districts and educational leaders should use the anecdotal data provided in this study as a basis for looking at their own curriculum. More inquiry and hands-on learning should be taking place in the school classrooms.
- Females do not shy away from the areas of chemistry, physics and engineering. Schools need to take cues from the organization of Science Olympiad teams and look at ways to make the physical sciences and engineering areas more accessible and attractive to females.
- Students enjoy learning. They like both collaboration and competition. Intrinsic and extrinsic rewards keep students motivated.

In summary, this literature survey captures the following key points:

- The importance of Mathematics and Science competitions to promote learning in these subjects.
- There are a number of factors which contribute to the popularity of Olympiads.
- One area in which Mathematics and Science Olympiads could be promoted is during the training of pre-service teachers in Mathematics and the Sciences.
- Some of the more experienced teachers regard problem solving competitions as being "difficult" and are not inclined to encourage their learners' participation in these competitions.
- Learners from disadvantaged communities, especially townships, appear to be on the "back foot" when it comes to participation in competitions such as a Science Expo due to lack of resources and teacher support. However, there is some support available for learners interested in Mathematics Olympiads.
- Education districts can become the key drivers in promoting Mathematics and Science Olympiads among the schools in the district.

## The District initiative

When one examines the literature survey for this paper, there is no doubt that a lot needs to be done in promoting Mathematics and Science Olympiads at schools, especially among schools from disadvantaged areas. In this regard, at least one recommendation of Wirt (2011), that of the role of the education district, should be relevant in a South African context. As stated earlier, this paper focuses on a district initiative to promote Mathematics and Science competitions among schools from disadvantaged areas. These schools were identified by their involvement in projects promoted by the district/ province or outside organisations (in collaboration with the district).

10 schools were invited to be a part of the initiative. This initiative consisted of activities which took place in two sessions. The first session consisted of a Natural Sciences Olympiad for grade 8 & 9 learners and Mathematics Relays for grade 10 & 11 learners. The second session consisted of a Science Olympiad (incorporating both Physical Sciences & Life Sciences) for grade 10 & 11 learners and Mathematics Relays for grade 8 & 9 learners. Each school had to send two learners to participate in each of the Natural Sciences and Science Olympiads and four learners to participate in each of the Mathematics relays. After each activity, learners were surveyed, via a questionnaire, which solicited their responses on a number of key issues such as:

- Their affinity for Mathematics & Science
- Their thoughts on representing their school in this district activity and the views of their friends, parents/guardians or other family members
- How they approached the Olympiad/Relays and their views of the questions in the Olympiad/Relays
- What they learnt from participation in the Olympiad/Relays

## The competition

The number of learner participants for each competition is shown in table 1.

***Table 1 Learner participation in the competitions***

| COMPETITION | GRADE | NUMBER |
|---|---|---|
| Natural Sciences Olympiad: | 8 & 9 | 16 |
| Sciences Olympiad | 10 & 11 | 20 |
| Mathematics Relays 1 | 10 & 11 | 40 |
| Mathematics Relays 2 | 8 & 9 | 40 |

The Natural Sciences Olympiad, for grade 8 & 9 learners, comprised 20 multiple choice questions and covered the various knowledge strands of Natural Sciences. The Mathematics relays for grade 10 & 11 learners comprised 15 mostly syllabus bound questions with the emphasis being on speed and accuracy. Learners worked in pairs for the Mathematics relays; a grade 10 pair and grade 11 pair.

The Science Olympiad, for Grade 10 & 11 learners, consisted of 20 multiple choice questions and included both Physical Sciences and Life Sciences. The Mathematics Relays for grade 8 & 9 learners comprised 20 mostly syllabus bound questions, also with the emphasis on speed and accuracy. They participated in pairs; a grade 8 pair and a grade 9 pair.

**Data from the survey of learners**

## Learner responses (from the questionnaire)

After each activity, learners completed questionnaires. The data received from the various groups of learners are summarised in table 2.

***Table 2: Learner completion of questionnaires***

| COMPETITION | GRADE | NUMBER |
|---|---|---|
| Natural Sciences Olympiad | 8 & 9 | 12 |
| Sciences Olympiad | 10 & 11 | 18 |
| Mathematics Relays 1 | 10 & 11 | 40 |
| Mathematics Relays 2 | 8 & 9 | 40 |

## Their affinity for Mathematics and Science

All learners indicated in their questionnaires their liking of Mathematics, Natural Sciences and Life & Physical Sciences. The actual statements of some of the learners are shown here:

### Mathematics (grade 10 & 11)

*"I like mathematics because I'm very brilliant at it; I find it easy; also my career needs mathematics"; "It's very fun doing maths and everyday there are new challenges -  that is why I like it very much"; "It is intriguingly fun and I love solving problems especially ones with numbers"; "Mathematics helps me to think critically. I am able to use my skill in maths in everyday life situation such as solving problems"; "It's one of my favourite subjects and it is very interesting and it also allows me to think more"; "It is fun to work with numbers and solve problems"; "I have always loved solving and counting as a child. It runs in my family and I always understand quickly".*

### Mathematics (grade 8 & 9)

*" I love mathematics because it teaches us discipline"; "Because you solve problems in many ways"; "It helps you solve problems"; "I need it to reach my goal of being a scientist"; "I like maths because I can use it on a daily basis"; "For me to understand and be better at doing mathematics I have to like it and practice more"; "It is very interesting and it gives me a chance to think hard and prepares me to be able to solve problems"; "I find it enjoyable and challenging and I like challenges"; "It is my best subject"; "Because I want to be a doctor"; " The reason is that it makes your brain fresh and also is good for you to count"; "Because I enjoy it at school and I am at working with numbers"; "It's a challenge and I love challenges"; "Because I love working with numbers and I understand maths statement, rules, equations".*

### Physical Sciences and Life Sciences (grade 10 & 11)

*"I like them because I want to pursue a career that combines both of the subjects"; " I'm interested about everything around me and how they are formed and where it all started and these subjects give me the information"; "In science we learn a lot of things that are surrounding us and they are subjects that are very helpful and also hard"; " I like the sciences because these are subjects that seem to be unique to me and I really enjoy it"; "It allows me to see things through  different eyes. It also teachers me a lot about nature"; "Because it teaches something that I do not know and how it is  made up it"; "Physical and Life Sciences open a new world to possibilities and innovation to better the world we live in". "Life science is interesting to know about our bodies and what it does"; "Both the subjects are interesting and are about our everyday life"; "Because they are talking about our lives- they are about us"; "Because they show us other information that we do not know"; "I like it because it's interesting and learn new things every day, especially in Life Sciences"; "These subjects help me to understand how the world functions in depth and as a whole" ; "I get to learn about the world around me from the smallest such as atoms to the biggest animals; it is exciting".*

**Natural Sciences (grade 8 & 9)**

*"Because I discover many things based on nature"; "Natural Sciences is a very interesting subject in my view"; "Because Natural Sciences tells us about life, natural things e.g. crops, water, people, etc."; "Because it helps us as young people to be scientists of tomorrow"; "Because I like learning about the human body system and Natural Sciences leads me straight to Life Science which I require for my career"; "You learn very interesting stuff and you get to see stuff you never saw before"; "I have a good teacher and she explains very well"; "It is interesting and people learn about new things and it's got adventure"; "The main thing that I like about Natural Science is that I don't just study all the time, I get a chance to see what I'm learning with my eyes"; "It gives much information about our universe and how we get life, which is from the process of photosynthesis"; "Learning about our bodies' immune system and all living creatures and what do they need in order to survive, make me become so enthusiastic, besides it's so fascinating to me."*

**Mathematics Relays (grade 8 to 11)**

*"I was very proud because there are many grade 10 learners and this shows me to work hard so that they will always select me"; "I'm a very competitive person so when I heard that I was selected I was so confident about this challenge"; "I was very excited and happy to be selected"; "I think the school chose me to participate because I improve my performance in maths every term"; "I was happy and really proud of myself. I felt very honoured too"; "When my teacher told me I was excited and happy to represent my school. "I thought we were going to write a test where you will be given time to think so that you can be the last man standing"; "I thought it was difficult thing because it's the first time I have come for this"; "I was surprised and nervous at the same time, but am happy that I was chosen"; "I was honoured and this has motivated me to be diligent in the future"' "I was very excited and happy to have been chosen".*

**The Natural Sciences and Science Olympiads (grade 8 to 11)**

*"My thoughts were to make my school to be proud of me"; "I was honoured to be chosen"; "I thought that I will be happy to represent my school in this Natural Sciences Olympiad"; "I thought that the Olympiad would be hard and that the questions were going to be very advanced"; "I was very happy, because I love Natural Sciences"; "I was so happy and read and heard about Sciences Olympiad"; "My thoughts was that I want to make my school feel proud and my teachers see that I'm really desperate to represent my school"; "I was shocked, I was curious to know what we are going to do there"; "Well I was very excited and honoured - I was a bit nervous though"; "I felt nervous because I thought when I mess this Olympiad up I would be embarrassing the whole school. But at the same time I was excited because I am doing what I love"; "I was firstly surprised and shocked that they chose me but then felt happy because you don't just choose anyone to represent the school"; "I thought I'm going to make my school proud of me and also I was a little bit scared and nervous because I have not been in things like Olympiads before"; "To go out there make my school proud and also to put my school in a higher level"; "I was so excited and happy for myself because I represented my school and I'm sure this will happen again in the future"; "I was so surprised when they selected me as a member of the school team"; "I did not think of this Olympiad as a competition really, it was just another way for me to extend my knowledge and understanding of Physical and Life Sciences"; "I was a bit worried about participating in it, but on the other hand I was proud to have been selected and hope I do get selected again in future for such competitions or projects".*

**Reaction of parents, teachers and friends**

When learners participate in competitions, there is always some reaction from family and friends. The learners' words below describe what the reactions from their parents and others were:

**Mathematics Relays (grade 8 to 11)**

*"My parents said I must do this very well, I must achieve this"; "They were very excited because if was representing my school and they know that I always do well in challenges like this one"; "They were extremely excited especially my mom"; "My family told me that they would support me and also pray for me. My friends said they would support and the school made a right selection"; "They were very happy and proud and encouraged me to keep participating in all sorts of competitions or whatever opportunities that comes my way"; "They were very happy for me and they were also so excited"; "They were very happy and they wished me good luck";" They said we must keep it up and they wished me all the luck"; "They were happy and they told me to do my best"; "They were so surprised and looked at me as if I want be able to win and I might get very disappointed"; "They just supported me and told me even it don't win I must just smile and move on"; "My teacher wished me good luck and my mother told me that she was proud of me also me and also wished me good luck"*

**Natural Sciences and Science Olympiad**

*"They were very happy, because now they know that I'm really serious about school every day"; "My mother said that I should make her happy and pass the Olympiad"; "They had wished me the best and said they would pray for me to make my school proud for participating in this district Natural Sciences Olympiad"; "They were so happy for me"; "My mom was very proud of me she told me that it nice to be honoured"; "My mother told me that she is proud of me and wished me good luck"; "My parents were so happy and they encourage me to study Natural Science"; "My mom was so happy for me and my dad encouraged me to read more so for him to know that I'm participating in the Natural Sciences Olympiad was very pleasing"; "My parents were impressed and wished me luck. My friends motivated me as well"; "They were very happy for me because my parents never did Physical Sciences and they give me their support to do very well in it"; "My parents were very excited when they heard the good news coming to me"; "They were so surprised when I told them about this"; "Honestly, my parents barely share my passion for these two subjects but judging from their facial expressions they were happy for me in a way"; "They were proud of me and the hard work I have been doing. They were also happy and excited for me"; "They congratulated me and they wish me all the best"; "They were surprised even though I was an achieving student in both Life Sciences and Physical Sciences".*

**What learners felt when working through the Olympiads and Mathematics relays:**

It would appear that for most of the learners, this was the first time that they had represented their schools in competitions of this nature. It was important to find out how they worked through the questions in the competitions. Some of their responses are shown here:

**Mathematics (grades 8 to 11)**

*"Firstly, the time was not enough. I thought of answering the questions as quickly as I can"; "Honestly, I was very nervous and a bit excited. I enjoyed it but now I have a headache"; "I was thinking about the time right away - my mind was not so focused as I was very nervous"; "I enjoyed the revision, it has freshens my mind. I really enjoyed it"; "I want to do it again. It was also easy"; "I need to show my mathematics skills and I was praying. Some answers I got without using my calculator"; "Because of the time we were given my mind didn't cope well I was just dead"; "It went so fast because of time"; "I was really nervous, but it was exiting"; "I was just worried if the answers were right and if I was going to struggle with them"; "Time, think fast, you got this, don't be nervous, you cannot let your team down"; "I thought that the questions were easy and if asked myself, why was I scared"; "I thought of all the things I learnt in class and was thinking of improving my maths marks"; "I was trying to remember some of the things we were taught, and some questions were a bit challenging because we were not taught these sections"; "There were few things while I was answering which was taught by my teacher. That was the sign that I am good listener"; "I think that I'm going to put my school in the first place"; "I was remembering the things my teacher teaches us at school. Also remembering that she wanted me to make the school proud"; "I saw the things that my maths teacher taught me at school".*

**Natural Sciences and Sciences Olympiad (grade 8 to 11)**

*"Do this for the school, make the school be proud. Do not only do it for the school do it for yourself and your family"; "Well just to do my best and let God lead me"; "I found out about the things that I didn't know. I also answered the questions according to my knowledge"; "I was so scared but I tried my best"; "The Lord helped me a lot, a sense of calm and interest was revolving around my mind"; "A lot of things were running through my mind. For example, there was a point where I asked myself if I represented my school well and also if I did enough"; "At first, I thought it was going to be easy and when I went through the paper and i saw the Life Science questions that made me very nervous"; "I found that some of the questions were difficult and needed some grade 10 work"; "I was so miserable when I answered the questions"; "The thought of me not making it; that I would maybe fail this test/competition.; that what I have written would turn out to be wrong; but either may I still am grateful to have been writing it"; "I found that Science Olympiad is interesting and I was also happy that the questions were not that hard".*

**What they learnt from participating in the District Competition**

**Mathematics Relays**

*"I learnt how to calculate quickly, how to solve mathematics when you have a given time"; "I have learnt that as a maths student you really to be faster when calculating in order to be ready for such challenges"; "I learnt that time is important in mathematics relays. Maths is fun when time is limited"; "Time is essential when writing a test or an exam. I have also learnt to be quick when writing and think fast"; "That I have to learnt to know how to work more under pressure"; "That I have to manage my time and think fast so that I get to answer all questions"; "I learnt that I must be calm and relaxed when answering"; "Team work is really good"; "I learnt that I must finish in time and be fast"; "That you have to be quick and know how to solve problem"; "I learnt that when you write mathematics you have to be calm and quick"; "I learnt that when you are going to do something be confident but don't be too confident because you don't know if other can do better"; "I learnt to think for myself and also use my brain more"; "You must confidence focus and also know why you are there"; "I learnt that at school I have be more serious not the to learnt and forget because maths will always be maths"; " I learnt that participating in the competitions is a great experience"*

**Natural Sciences Olympiad and Science Olympiad**

*"I learnt to not to rush to answer questions because you may make mistakes during the exam time"; "I learnt that taking part in things like these is very helpful because I am passionate about Science"; "I learnt that I should focus more on my studies because there are more opportunities like this one through my studies especially when you are doing Maths and Science"; "I learnt that you must not only focus on what you know best only try focus on the grade to work in order to know something that is not thought in grade 11"; "I learnt many things in this Science Olympiad"; "I learnt there is more to Physical and Life Sciences and not only what our syllabus tells us or what our teachers teach"; "That I should write even harder, knowing that there are opportunities out there for me, but it all can only happen for me if I stay focused, work hard and strive to attain my goals in life"; "That I should believe in myself and have confidence because at first I was so nervous that the questions will be difficult and I was scared of other schools but that ended up well"; "I learnt that believe in yourself and being confident can bring success to your future"; "I learnt that science is important to everyone because you are a human being"; "You have to use your mind"; "Lots of interesting facts"; "I have learnt to read and then answer the questions"; "Now I want to do more about Natural Sciences and not forget the things I have learnt before"; "I learnt that no matter what the people say about you cannot do it, you should just walk tall and do your best"; "I learnt to try to find out more information than I already know and explore Natural Sciences"*

**Trends from the learners' responses**

There is no doubt that learners provided some rich data for this paper. In this regard, the trends emerging from their responses are written with a view to examining trends and patterns of coherence. Some of these trends are:

- Learners participating in the Mathematics relays and Science Olympiads were the top learners of these schools and all showed a likeness or affinity for Mathematics and Science.
- Their views also indicated how interesting they found these subjects and what they learnt from these subjects.
- They were very proud of being d as members of their school teams for this district competition.
- Their parents, as well as some teachers and friends, congratulated them and wished them well for the competitions.
- They realised that these types of competitions were not easy and that they had to work fast and accurately, especially for the Mathematics relays.
- They learnt that time management is a key and that team work is important during the relays.
- Those writing the Natural Sciences Olympiad and Science Olympiad realised the importance of these subjects and that achieving well in the subject depends on how hard they worked.
- It was very interesting and reassuring to note that some of them linked these subjects to their future careers.
- It was also clear that participation in the district competition boosted their confidence in the Science subjects

***Table 3: Categories for prizes***

| MATHEMATICS | SCIENCES |
|---|---|
| Grade 8 (top 3 learners) | Grade 8 & 9 Natural Sciences (top 3 learners: individual) |
| Grade 9 (top 3 learners) | Grade 8 & 9 Natural Sciences (top 3 schools – combined) |
| Grade 10 (top 3 learners) | Grade 10 & 11 Sciences (top 3 learners: individual) |
| Grade 11 (top 3 learners) | Grade 10 & 11 Sciences (top 3 schools – combined) |

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## Results of the Competition

The points were for the various events were calculated as follows: 10 points were allocated for first position; 6 points for second position and 2 points for third position. In this regard, to balance both the Mathematics and Science components of the District competition, prizes were awarded according to the categories shown in table 2. Thus, a maximum of 80 points was on offer, 40 points for Mathematics and 40 points for the Sciences

The next table shows how the schools performed:

***Table 4: Categories and points scored***

| Name of school | Grade 8 Maths | Grade 9 Maths | Grade 10 Maths | Grade 11 Maths | Natural Sciences Individual | Natural Sciences combined | Science Individual | Science combined | TOTAL |
|---|---|---|---|---|---|---|---|---|---|
| A | | 10 | | | 6 | | | | 16 |
| B | 10 | 6 | 6 | 6 | 6 | 10 | | | 44 |
| C | | | | | | | | 6 | 06 |
| D | 2 | 2 | | | | | | | 04 |
| E | | | | 2 | | | | | 02 |
| F | | | | | | | | 2 | 02 |
| G | | | | | | | | | 00 |
| H | | | 2 | | 6 | 6 | 8 | 10 | 32 |
| I | | | | | | | | | 00 |
| J | 6 | | 10 | 10 | | 2 | 10 | | 38 |
| | | | | | | | | | |
| TOTAL | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | |

Of the 10 schools, only two schools did not get any points at all. The eight other schools all managed some points. All prize winners were invited to the District Science Awards. The top learners in each category received gifts and certificates. The top three schools received trophies and certificates.

**Some interesting points (about the schools)**

School B (the top school) is located in a former Black area and had only Black participants; School J (the second school) is located in a former Indian area but the majority of learners who represented the school were Black. School C is located in a former Coloured area and had both Black and Coloured participants

**Findings**

- It would be reasonable to say that this district initiative to promote Mathematics and Science competitions among schools in disadvantaged areas has provided some useful pointers in taking Mathematics and Science competitions to learners at these schools. The rich data emerging from this district initiative is now incorporated in the findings of this paper:
- There are various ways in which Mathematics & Science competitions could be promoted at schools. One of these could be for education district to target a few schools based on certain criteria and have inter-school competitions at a local level.
- A district initiated competition should be well planned and structured. Learners should know what is expected of them at the competition.
- Since the majority of learners may be participating in the competition for the first time, it is important for the competition to be conducted in a non-threatening environment. In the district competition described in this paper, learners worked in pairs for the Mathematics relays and the questions appeared to be within their scope. The questions in the Natural Sciences and Science Olympiad also appeared to be within the scope of the learners. Thus, it would be fair to claim that the competition was not intimidating for the learners. This would probably explain why learners were eager to participate in more competitions of this nature.
- Just as learners represent their schools in sporting codes and cultural activities, learners are proud to represent their schools in Mathematics and Science competitions, even at a local level. In so doing, their confidence, in their own abilities, is boosted. Learners would like to do well in these competitions and may go into these competitions having done some preparation and revision. This has a positive spinoff for them as their performance in their Mathematics and Science subjects at schools are likely to improve further.
- Participation in local competitions also gives learners the confidence to go further and participate in regional, provincial and national competitions. In fact, of the 10 schools which participated in this district initiative, eight of the schools have learners who are part of the Siyanqoba Regional Olympiad training programme (for Mathematics) in the district. The top three schools have 33 of the 80 participants in the programme (School B – 15; School J – 10; School H – 8). All these learners wrote the first round of the SAMO on 15 March 2017. Further, all schools which participated in the district competition had registered learners to write the Natural Sciences Olympiad and the National Sciences Olympiad for 2017.
- When learners participate in Mathematics and Science competitions, they become more aware of the importance of these key subjects and the need to do well in these subjects. Top performances in Mathematics, Physical Sciences and Life Sciences give learners direct access to Science and Engineering programmes at universities.
- There is a need to increase the pool of top Mathematics and Science learners from all schools, especially those from disadvantaged areas. This may be done through various initiatives, including getting top learners from schools in disadvantaged areas to participate in Mathematics and Science competitions. This may boost the number of learners taking up Science and Engineering careers. These learners can serve as role models to other learners from their schools.

## Conclusion

There are a number of obstacles which prevent learners from disadvantaged schools from being prepared for and participating in National Mathematics and Science competitions in South Africa. These obstacles include a lack of teacher and parental support, lack of resources and, perhaps, a lack of a competitive environment or an Olympiad culture at the schools. This means that learners at these schools are not given the opportunity to develop or showcase their talents outside their school environment. This paper has shown that it is possible for education districts to intervene and change this unfortunate state of affairs.

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# PARTICIPATION AND CHALLENGES IN THE INTERNATIONAL PHYSICS AND CHEMISTRY OLYMPIADS

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## 1. INTRODUCTION

South Africa's recent participation in the International Physics Olympiad (IPhO) and International Chemistry Olympiad (IChO) have given learner participants exposure to a world of science that they would never have come across in their high school or national science expo environments. Just the experience itself of being a competitor and meeting young brilliant minds from all corners of the world has motivated them to excel; they have all become top achievers firstly in their respective matric year and subsequently at University.

Among the many challenges, that we currently face in preparing these students to participate, are their limited knowledge of science and mathematics that they bring from our schooling system. Such International Olympiads have enabled us to gauge the level of science taught at high school in South Africa as compared to other countries, be they first world or developing countries. It shows curriculum developers and us the urgent need to re-shape South Africa's school curriculum in physical science to align ourselves to international standards.

In this paper, we briefly describe the IPhO and IChO, and discuss the challenges faced in our recent involvement at this level. We describe our selection process and how staff and postgraduate students at the University of KwaZulu-Natal (UKZN) assist in the overall preparation of the respective teams. We also motivate why participation must continue and how teachers and University academics can get involved in preparing our learners for international participation, while also making science more attractive and exciting to a larger number of learners.

This paper also allows for a platform to answer some relevant questions pertaining to our readiness for participation at an international level. These questions are: 1. Are our teachers equipped to deliver the Physical Science Curriculum adequately? 2. What can we do to improve teaching and learning of Physics and Chemistry? 3. Do our students have the ability and potential to work at a much higher level in school? 4. What is the curriculum gap between High School and University Sciences? 5. What role do we see for Universities in improving our Sciences at school? The responses to these questions are limited to succinct responses from the authors, in their capacity as leaders, coaches and mentors that train our learners to partake in international physical science Olympiad events. Most of these questions have far-reaching interpretations and are to some extent controversial. It is left for the reader to examine relevant reports and surveys done by various organisations (Government and NGO) on the status of our country's current education system. 2. WHY MUST SOUTH AFRICA PARTICIPATE IN INTERNATIONAL OLYMPIADS?

Participation in international Olympiads has tremendous advantages for both the learner and the country as a whole (Campbell and Walberg 2010).

For the learner, these competitions are the primary tools to challenge the most gifted and stimulate their learning to reach higher scientific levels. The learners are exposed to new scientific theories, concepts and tools that they would otherwise never encountered in school, since international Olympiads have syllabi based on first year University material and often beyond. Learning this material at a young age is itself an advantage, which expands their knowledge base to tertiary education levels. In addition, they get to meet learners of their age group from all over the world and share their aspirations and dreams. The participants also get to experience the culture and society of a different country, visit famous science related institutes and experience the exhilaration of being in world-class research laboratories. They also get on occasion to meet with Noble prizewinners. By interacting with foreign leaners they also get to gauge their abilities and get motivated (Jordens and Mathelitsch 2009). Research has also shown that learners participating in international science Olympiads tend to choose careers in science or mathematics and also achieve great heights within their chosen fields (Sahin, Gulucar & Stuessy 2014).

By far, the most important advantage for the country is that it gives us insight into the level of science taught and studied in other countries and what South Africa needs to do, to align itself with international standards. It also gives credence to the world that science is done in Africa as well. Africa is highly underrepresented in physical science at international events. In 2016 only Nigeria, South Africa and Ghana participated in the IPhO. Egypt will participate for the first time in 2017. IChO participation in 2016 only included Nigeria, South Africa and Egypt.

South Africa must participate in International Olympiads whether we are ready to do so academically or not! Current participations is not reliant on training a whole generation of learners to win medals or obtain honorable mentions but to familiarise mentors and participants with such competitions on an international stage. Many countries that started participating in international Olympiads decades ago with poor results are today producing medalists.

## 3. PARTICIPANT SELECTION

Both our IPhO and ICho selection are based on similar criteria. The initial selection is made from the National Sciences Olympiad's grade 10 and grade 11 Physical Sciences Olympiad. These Olympiads consist of 15 chemistry and 15 physics questions, which are based respectively, on the Curriculum Assessment Policy Statement (CAPS) syllabi. From this cohort the top 15 students with the highest points in each of the chemistry and physics sections are selected to move onto the next round. Each of the two groups of top 15 learners then writes either a physics or chemistry selection test. The latter tests consist of more advanced questions that incorporate grade 12 and some university level questions. In the physics selection test, some questions incorporate elements of calculus in order to test the mathematical aptitude of the learners. The tests are prepared, moderated and assessed by academics from the School of Chemistry and Physics, UKZN. From the physics test, the top 5 with 2 reserves are chosen to participate in the IPhO and from the chemistry test; the top 4 with 2 reserves are chosen to participate in the IChO.

As can be judged, this method of selection is not ideal. The selection obviously depends primarily on whether a school participates in the Physical Sciences Olympiad or not. We need a much larger pool from where learners can be selected. Most countries have at least a three-tiered selection process – two national selection rounds and then use other regional Olympiads to do final selections for the IPhO or IChO. Financial constraints also dictate which students will eventually make the teams. This is the case with many countries where international Olympiad participation is not funded by government or wholly by private institutions. All these factors often lead to selecting students that are not always the most talented or the ones we want.

Team South Africa for the IPhO consists of 5 learners and usually two leaders, however since 2014, only one leader could be accommodated due to financial constraints. For the IChO, the team consists of 4 learners and 2 leaders. Participating countries must register the teams prior to each Olympiad and are expected to bear the cost for registration fees as well as travelling costs. The host country incurs the costs of accommodation, subsistence, tours, banquets, opening and closing ceremonies, prizes and all other costs.

## 4. IPhO PARTICIPATION

The International Physics Olympiad was first help in Poland in 1967 (behind the iron curtain) and has been held ever since, for the most part, in a different country each year. For more details on the history and other interesting information about the IPhO, visit their website at http://ipho.org. South Africa was first invited to attend the 2012 competition by the then, and current IPhO president, Prof. Hans Jordens, after witnessing the very successful International Junior Science Olympiad (IJSO) hosted in Durban in 2011. It should be noted that South Africa's first participation was exempt from a two-year prior observer status. South Africa has thus far participated in five competitions (see Table 1.). In July 2017 we will compete in the 48th IPhO in Yogyakarta, Indonesia – according to their webpage there will be 86 countries taking part with 415 learner participants.

The competition as a whole runs between nine and ten days. The competition consists of two five hourlong exams, one theoretical and one experimental, written on two separate mornings. The day before the exam, unseen problems are first introduced by the host country and then discussed by the international board, consisting of the leaders from the participating countries. These deliberations always run into the early parts of the next morning of the day the competitors write the exam. Both exams are graded by the respective country leaders and then compared to marks obtained by official markers during a moderation session. Information about how medals are distributed can be found in the statutes of the IPhO that can be obtained from the IPhO webpage.

**Table 1: South Africa's IPhO participation since 2012**

| IPHO# | Year | City/ COUTRY |
|---|---|---|
| 43 | 2012 | Tallin, Estonia |
| 44 | 2013 | Copenhagen, Denmark |
| 45 | 2014 | Astana, Kazakhstan |
| 46 | 2015 | Mumbai, India |
| 47 | 2016 | Zurich, Switzerland and Liechtenstein |

The syllabus of the IPhO is based primarily on first year University physics, with limited content also taken from higher levels. Since matmatics is core in solving physics problems, the syllabus also contains the necessary mathematics that is needed, such as integral and differential calculus, and other advanced topics. In terms of content and concepts, the South African school physics and mathematics syllabus only prepares learners for about 30% of what is actually required for the IPhO, and that, at a very basic level. This is by far the most difficult of all challenges we face in participating; the initial limited knowledge of our selected team.

Our IPhO team (together with reserves) is typically announced in November or early December and training via dedicated interaction with the team leader usually begins in February, once the team is finalised. The team is provided with sufficient study material that includes previous years problems and solutions, textbooks, study material from other countries and physics lecture notes from UKZN academics. This information is also available on a webpage hosted at UKZN. In most years, when the majority of the team comes from the regional Durban area, 3-4 hour-long training sessions are run on average, every other Saturday morning between the months of February and June. Team members from other parts of the country are forced to self-study and sometimes Skype-in to follow the sessions. By far the most challenging aspect of the initial training is getting the learners familiar with the required .

The most intense training session is done when we hold a weeklong camp at the School of Chemistry and Physics on the Westville Campus at UKZN. This camp usually takes place during the school break, about two weeks before the team leaves for the competition. Daily routines are basically, morning lectures from physics' lecturers on topics that were not covered during the Saturday sessions, and afternoon experimental work. At this stage of the training it is assumed that most of the students have a descent knowledge of the IPHO theoretical syllabus, so more attention is paid to getting their experimental skills up to scratch. This is an arduous task since very few schools in South Africa are equipped with a functioning physics laboratory and it has been seen that, in some cases, students are even met with difficulty in setting up simple electrical circuits. Our experimental training has thus far obtained the best rewards. In last year's IPHO (2016), our team managed a very respectable average of around 60% for the experimental exam. This we attribute to the intensive laboratory exercises that they go through during their training. This training consists of performing most of UKZN's second year physics laboratory tasks under the constant supervision of two very competent physics PhD students. The learners also experience examination conditions by performing short experimental tests.

Figure 1: IPhO team, together with Mervlyn Moodley (Leader) at the School of Chemistry and Physics, UKZN, physics laboratory.

## 5. IChO PARTICIPATION

South Africa was warmly welcomed and fully acknowledged as a new participating country to the International Chemistry Olympiad family in 2016. A two-year observer status was a pre-requisite prior to acceptance as a fully recognised IChO participant. This was accomplishment through the drive, commitment and effective communication channels of the National Science Olympiad steering committee.

The inaugural South African team participated in the 48th International Chemistry Olympiad in Tibilisi, Georgia accompanied by two team leaders. Despite the tough theory and practical examinations, the team gave a good account of themselves and kept the South African flag flying high as a proud new participating nation. It was an awe-inspiring trip for both leaders and learners. Although no medals were achieved, the learners' results could be highly praised especially with their performance in the practical examinations. This was indeed a strong indication of our ability to compete on a world stage. The leaders left the Olympiad with a strong sense of new learning methodologies as well as teaching strategies with hope and belief that they would return with a team well prepared and ready to take on the world. More information on the history of IChO can be accessed from https://www.iuventa.sk/en/Subpages/ICHO/ICHO.alej and information on details of the 49th hosting of the ICHO can be accessed from https://icho2017.sc.mahidol.ac.th/. The 49th IChO will be hosted in Nakhon Pathom, Thailand from 6 – 15 July 2017. The theme for the 2017 IChO is "Bonding the World with Chemistry".

Learners write a 5-hour theory examination and perform a 5-hour practical which entails calculations and answering of practical related questions. The Scientific Committee of the host country prepares the practical and written theory examinations. Team leaders are given a tour of the laboratory facilities where the practical examination will be conducted in order to make recommendations or query any uncertainties pertaining to the practical examination to be undertaken. A panel discussion involving all team leaders is conducted to recommend changes and finally accept the practical examination paper. The same protocol is adopted for the written examination paper. Upon completion of both written and practical examinations, official markers, assigned by the scientific committee of the host country, carries out the marking. Marking of the examinations by team leaders of the respective countries follows this. A moderation of the assessment of practical and written theory examinations is carried out after the marking. Finalisation of marks and allocation of medals are concluded at a marks meeting. The competition concludes in a prize-giving ceremony and a gala dinner.

Figure 2: IChO team, together with Ajay Bissessur (Leader) at the School of Chemistry and Physics, UKZN, chemistry laboratory.

## 6. QUESTIONS

In the bigger scheme of Olympiad participation across all facets, we need to reflect on the performance of our students at an international level and answer crucial questions pertaining to mathematics and science education currently taught at primary and secondary levels. We thus pose the following questions, together with our responses, from a mentor and leader perspective. We hope to gain an understanding of our roles as teachers and whether we can assist through Olympiads in providing feedback as to what mechanisms can be put in place to better equip our learners to handle mathematics and science education at higher levels, before even considering international levels.

**Are our teachers equipped to deliver the Physical Science Curriculum adequately?**

In our opinion, partially yes but there are certainly problem areas that can be identified. Most teachers, especially from ex-model C or private schools, are suitably qualified for the posts that they have been appointed to, however they may lack 'academic depth' as discussed in (Rusznyak, Balfour, Van Vollenhoven and Sosibo 2016). A grey area does exist where incumbents, appointed to government school posts, lack the suitable qualification (Hofmeyr and Draper 2015) and have been appointed as a direct consequence of a lack of qualified applicants or through unethical means. These scenarios are at the mercy of hierarchical bodies with subsequent audits. A lack of zest, ability, leadership, communicative and organisational skills of the individual teacher is another area of concern

**What can we do to improve teaching and learning of Physics and Chemistry?**

There is room for improvement throughout the broad spectrum of Government, ex-model C and private school institutions. Improvement lies in the sustainability of the system in place, monitoring of the success of the system, upgrading the system on a regular basis and funding the system. Currently there are numerous systems in place to improve teaching and learning of STEM. These systems are both locally and internationally developed. South African schools tend to adopt systems that have been developed internationally, in mainly European and American schooling systems – our lawmakers need to monitor the evolution of these foreign systems and keep abreast at what the greater third world, yet ancient, education systems like those found in India and China can offer us.

An aspect that has been receiving focal attention in improving teaching and learning of STEM are technology-based systems such as You-tube, learning websites such as the Khan Academy, free e-textbooks, on-line tutorials and online -benchmarking. Even if schools lack the basic infrastructure to conduct physics or chemistry demonstrations, there are plenty of web resources that can bring these demonstrations into the classroom via cleverly designed media applications such as the PHET (https://phet.colorado.edu) interactive simulations for the sciences. The department of basic education should look closely at how these tools are currently used at tertiary institutes within South Africa.

Teachers also need to convey, to the young impressionable learners, their 'love' and excitement for the subject. The quote by the famous mathematician R. L. Wilder sums this up best with respect to mathematics, which of course can be directly transferrable to the sciences: " ... making mathematics exciting to a pupil is for the teacher to be excited about it him(her)self; if he(she) is not, no amount of pedagogical training will make up for the defect."

A more extreme measure to improving teaching and learning would be that educators who teach science and mathematics should be equipped with a BSc degree in these specialisations. Teachers need to experience the vastness of their chosen subject and not only be limited to what the CAPS syllabi dictates them to teach learners, within the school environment. Doing a fully-fledged University BSc degree would also put an end to the many misconceptions about science and mathematics that learners carry with them from school to University. As lecturers involved in the first year teaching of physics and chemistry at UKZN, the authors have first hand knowledge of how learners are literally taught incorrect science in high school. The idea of a BSc degree for educators is not a new concept in democratic South Africa. In fact, one of the authors (MM) was involved in the 'BSc Programme for Northern Cape Educators' run at UKZN between 2010 and 2014. In teaching these educators two physics modules at the second and third year level it became evident that confidence and knowledge content of the educators was dramatically increased. The success of this programme has been documented by the CASME (2016).

**Do our students have the ability and potential to work at a much higher level in school?**

Our learners are no different from any other young impressionable human being found in any other corner of our planet. Potential is a factor that all human beings possess, however the individual cannot always execute that potential, in many instances by themselves, and needs the guidance of experts or mentors in order to excel. This is where highly knowledgeable and motivated teachers should be playing a part.

Learners showing interest in science and mathematics should be identified at an early age and given enough stimulation to maintain this interest.

It is also a well-known fact that all individuals may not have the aptitude, desire to follow the sciences or are mathematically inclined. Certainly the cohort who is interested in science and mathematics would be able to handle these subjects at a higher level. Science and mathematics should not be forced onto learners who do not show an interest in it. Learners certainly worked at a higher level before the standard of science and mathematics taught in our schools were drastically reduced.

**What is the curriculum gap between High School and University Sciences?**

The gap has become enormous both in content and degree of difficulty. Even students who obtained distinctions for mathematics and physical science in matric find it difficult to make the cut during their first year at University (Govender & Moodley 2012). By far mathematics is the biggest problem.

Over the past twenty years or so, the standard and content of science and mathematics taught in our schools has been lowered so significantly to the extent that there is no more an easy transition for learners from school to University. What we are left with now are school syllabi that are limited in content and lack depth. This also has repercussions on South African Universities as well, in that they now have to make up for content not fully or properly covered in schools.

There is unfortunately no proper and official communication between schools and universities to close the curriculum gap and the reasons for this is not well understood. Besides, University science departments have no interaction with the Initial Teacher Education (ITE) programmes. University syllabi are much more rigorous and intensive than those taught at school and University students at first year levels especially, battle to deal with the volume and the level of work presented to them.

**What role do we see for Universities in improving our Sciences at school?**

By far the most important role that Universities can play in improving the sciences at school is to dictate a curriculum restructuring to the Department of Basic Education. The knowledge brought to University by high school learners today is not what it was twenty years ago and that itself was not enough at today's international standards. To keep up with overseas countries our school science and mathematics curriculums must move closer to A-levels. University science departments should also play a role in the selection of mathematical and science content taught in ITE programmes.

Universities must be taken to the schools. Universities have to be more proactive in helping learners choose a field of study. Just advertising what is offered is not enough – the Universities need to explain exactly what a particular degree or study choice entails including highlighting its level of difficulty. This could also curtail the very exorbitant dropout rates in science, engineering and mathematics, that South African Universities experience, due to first year students thinking that these subjects are as easily accessible as they were during their high school careers.

Some institutions, like for example the University of KwaZulu-Natal, has numerous programmes currently in place to achieve some kind of interaction with schools, viz.:

1. Open days
2. National Science Week
3. Be A Scientist for a Week
4. The Great Science Show Off

Activities by the Science and Technology Education Centre (STEC) that include:

Chemistry magic shows, physics demonstrations, talks and activities, laboratory visits and demonstrations.

6. Visits to schools by the School of Chemistry and Physics which includes giving talks, carrying out chemistry magic shows and execution of physics demonstrations.
7. Science expos hosted by the School of Chemistry and Physics e.g. Annual ESKOM Science Symposium.
8. Collaboration with schools on projects assigned to learners.

Web resources and information accessible to school students via the School of Chemistry and Physics website.

The obvious generalization of these questions would be its interpretation in the broader international arena. This requires a more technical response, looking in detail into the respective syllabi of the IPhO and IChO, what is currently being taught in our schools and what the ITE programmes offer our educators– this we shall revisit in a follow-up publication.

## 7. CONCLUSION

Participation in international Olympiads brings a new dimension to learning, teaching and reflection to our current primary and secondary education system. South Africa has participated regularly in the IPhO since 2012 and there has been a consistent improvement in overall results from year to year. Training has also been refined over these years but there still is plenty of room for a more radical approach to get our learners on par with their overseas contemporaries. Participation in the IChO began last year with satisfactory results and participation will continue – progress can be scrutinized in forthcoming years. In the selection process for both Olympiads, it is evident that we need a larger pool of learners to select from, and there should ideally be more tiers associated with the final selections. Even with lack of support and funding from government and private agencies, academics from the School of Chemistry and Physics at the UKZN give up their valuable time and personal resources to help prepare our teams. With regard to the questions we presented, it should be again reiterated that the answers we propose are from the perspective of University physical science lecturers, and leaders to our international Olympiad teams.

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