Education and Skills Development

MAPPING THE LANDSCAPE OF STEMI OLYMPIADS AND COMPETITIONS IN SOUTH AFRICA

Report prepared for the Department of Science and Technology

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Submitted by

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ABBREVIATIONS AND ACRONYMNS

ASTEMI	Association of Science Technology Engineering Mathematics and Innovation
DST	Department of Science and Technology
ICT	Information and Communications Technology
IMO	International Mathematical Olympiad
ISMC	International Singapore Maths Competition
SAASTA	South African Agency for Science and Technology Advancement
SES	Science Engagement Strategy
STEM	Science, Technology, Engineering and Mathematics (Used in reference to subjects and content areas)
STEMI	Science, Technology, Engineering, Mathematics and Innovation (Used in reference to Olympiads)
TIMSS	Trends in International Mathematics and Science Study
YiSS	Youth into Science Strategy

EXECUTIVE SUMMARY

The Department of Science and Technology is on a mission to build a culture of science in the schooling system. Olympiads and competitions in science, technology, engineering and mathematics (STEM) subjects are important in this endeavour as they help to promote the different ways that science can be learned and expose learners from diverse backgrounds and contexts to the exploratory and practical nature of maths and science.

Mapping the landscape of STEM promotion by means of Olympiads and competitions is an important step towards the expansion of such interventions. This report provides such a mapping, based on the responses of thirteen participating organisations. It shows which organisations are involved in the promotion of STEMI Olympiads and competitions in South Africa, the size and scope of the Olympiads and competitions including the targeted schools, learners, their subject content, the types of activities involved, and the incentives and rewards offered to participants. It does so against the background of the various learning outcomes and benefits of participation for learners, while also considering the challenges encountered by the organisations and their strategies on how to increase the number of participants.

Based on data received from the thirteen participating organisations it is evident that the number of learners involved in STEMI Olympiads and competitions has increased markedly between 2014 and 2017, reaching over the four years combined over 2.1 million learners. While most organisations target all types of schools (rural and urban, and of all quintiles), there is a marked bias in participation towards learners in urban school contexts. The most common activity involved are smaller scale contests and the large scale Olympiads. They frequently use a multiple choice question format, but can also include project and challenge-based assessment tasks, short answer or essay-based assessment. Other activities include quizzes, speeches and debates, model building competitions, programming competitions as well as expos. Some of the activities are held in school or both, in and out of school, and they may be adjudicated either by judges, school teachers, the testing organisation, or by automated software. The analysis further shows that a wide range of STEM-related

content areas is covered by the Olympiads and competitions from Basic Numbers and Operations to Algebra and Geometry, and from Astronomy to Nanotechnology and Science in Society.

The participants in the study made a number of recommendations of ways in which learner participation in STEMI Olympiads and contests can be expanded. They are listed the final part of the report in relation to different stakeholders including the Department of Science and Technology and the national and provincial Departments of Basic Education, teachers and subject advisors, and in relation to key issues such as the training of teachers and learners, the identification and tracking of learners, communication and competition promotion.

1. Introduction

The Department of Science and Technology (DST), through the South African Agency for Science and Technology Advancement (SAASTA)[1], have been working together with a number of organisations and associations in order to promote awareness and create interest in Science, Technology, Engineering and Mathematics (STEM) areas at both primary and secondary school levels. Olympiads and competitions are one way in which STEM subjects are promoted in South Africa. The main purpose of these Olympiad and competitions is to promote interest in the sciences[2], to inspire excellence in science education and to discover talent among school-going learners. The Olympiads are credited as having outstanding impacts on education (Verhoeff, 1997).Other STEM competitions include mathematics challenges, contests, quizzes, debates, speeches, model building and expos.

The main purpose of these competitions is to promote interest in the sciences, to *inspire excellence* in science education and to *discover talent* among school-going learners.

The mapping of the landscape of science competition[3] activities in schools is part of the DST's *Science Engagement Strategy* and *Youth into Science* strategies (YiSS). Both strategies aim to enhance participation, performance and awareness of science and science based careers of school-going youth and undergraduates in STEM subjects. Furthermore the YiSS strategy aims to produce a high number of quality science, engineering and technology inclined high school graduates through cultivating science and technology awareness and literacy, and through engaging more school learners and undergraduates to pursue careers in STEM subjects. In addition, the *YiSS* is intended to improve coordination of, and encourage, science promotion, communication and engagement activities across various sectors such as government departments, schools, universities, science councils, museums, and other partners outside the public sector. This exercise of mapping the landscape of science competition activities in schools will therefore serve as a reference point for the work

[1] SAASTA, which is the key South African institution for promoting science, is a business unit of the National Research Foundation.
[2] This covers the entire STEM (Science, Technology, Engineering and Mathematics)
[3] The term "competitions" will be used to cover the whole 'Olympiads and competitions' expression

envisaged in the Science Engagement Strategy, particularly with regard to Strategic Aim 1, which is “To popularise science, engineering, technology and innovation as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers”.

The first strategic aim of the *Science Engagement Strategy* relates to science education support and states that some science and mathematics Olympiads and competitions enable learners to refine and display their own understanding of the knowledge and techniques acquired from formal classroom teaching and learning provided by the Department of Basic Education (DBE).

Science Competition activities have much to offer in education. The availability of good competitions is beneficial for education in almost any discipline. If the regular curriculum is not sufficiently challenging, then talented learners should be encouraged to participate in extracurricular competitions. It is asserted that competitions are a good measure of how well a discipline is accepted and integrated into the curriculum: a healthy, diverse set of competition events is a positive sign, whereas a lack of good competitions may in some cases be interpreted as a negative sign (Verhoeff, 1997).

Competitions are a good measure of how well a subject discipline is accepted and integrated into the curriculum

Olympiads are competitive events where learners participate in a test. These tests may require multiple choice or numeric answers, or a detailed written solution and proof. There is usually an enthusiasm among learners to compete in mathematics competitions (Verhoeff, 1997). This is a good sign for the progress of mathematics education. Most competitions test learners' knowledge beyond the school syllabus and expose what the learners cannot do while a good competition should actually be a platform to reveal what learners can do (Verhoeff, 1997; International Singapore Maths Competition, 2016).

The Association of Science Technology Engineering Mathematics & Innovation (ASTEMI) is a collaboration that brings organisers of STEM Olympiads and competitions together – including professional and academic societies, universities and other tertiary institutions, private enterprise and government – to expand,

coordinate and promote Olympiads and Competitions to a broader base of learners and educators in South Africa.

There are a number of STEMI Olympiads and competitions that are currently undertaken in South Africa. However, it is not clear to the DST who all the role players involved in the promotion of mathematics, science and technology are. DST estimates that between 300 000 to 400 000, mostly urban, learners participate annually in STEMI Olympiads and competitions in South Africa (DST, 2016).

This descriptive-analytic report was commissioned to identify the role players in this area and, more importantly, to outline how the existing competitions are organized and coordinated. Recommendations can then be made on how these programmes can be expanded. This report also includes a description of how other countries use the modality of Olympiads and STEMI competitions to promote science engagement. With this in mind, the research questions which guided this study and provide the structure for this report were:

1. Which organisations and associations are involved in STEMI Olympiads and competitions in South Africa?
2. What is the size and scope of the science competition activities that these organisations host?
3. What are the types of tests and other assessment instruments administered in the science competition activities?
4. What incentives do the organisations offer participants of the science competition activities? (e. g. bursaries, cash prizes, trips)

2. Competitions as a way of learning

Before the methodology and findings of the study are discussed, it is important to examine why STEMI Olympiads and competitions are used as a platform for STEM engagement. We briefly examine international practice and then turn to what researchers have found with regard to the impacts of participating in these activities.

Internationally, countries emphasise the importance of teachers presenting maths and science in a dynamic, innovative and creative manner to the learners.

Table 1: STEMI competitions hosted in some countries around the world

Countries	Competition name	Activities
Canada	The DuPont Challenge	Science essay writing contest: (700-1000 words on the science topic of your choice in broad categories of food, energy, environment, and innovation)
	Canadian Mathematical Olympiad	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.
	Canadian Open Mathematics Challenge	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.
	ExploraVision	Learners work in groups to simulate real research and development.
Hong Kong	International Junior Science Olympiad	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs
	Hong Kong Physics Olympiad	
Singapore	International Singapore Maths Competition	A series of exams used to challenge high achievers learners who have considerable experience in both solving highly challenging problems and writing proofs.
United States of America	3M/Discovery Young Scientist Challenge	Learners need to submit a 1-2 minute video which describes a new innovation or solution that could solve or impact an everyday problem.

	Team American Rocketry Challenge	Teams design, build and fly a model rocket that reaches a specific altitude and duration determined by a set of rules developed each year.
	Science Olympiad	School-based teams of 15 learners in grades 6-12 who prepare, coach, and practice throughout the year to compete.
	Who Wants to Be a Mathematician	A game show in which high school learners compete for cash and prizes by answering multiple choice mathematics questions.
	United States of America Mathematical Olympiad (USAMO)	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.
China	China Mathematics Olympiad	Participants must solve three problems every day in four and half hours for 5 days.
	China Girls Maths Olympiad	
India	Indian National Olympiads (Mathematics, Physics, Chemistry and Biology)	Olympiad examinations in different subjects. A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.
Russian Federation	All-Russian Mathematical Olympiad	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.
	St. Petersburg Math Olympiad	
	Moscow Math Olympiad	

	Leonard Euler Math Olympiad	
	Russia Sharygin Geometry Olympiad	
Brazil	Expo-Sciences International (ESI)	One of the largest events in science, focusing exclusively on the scientific creativity of young scientists. Leisure activities in science and technology.
	Brazilian Mathematics Olympiad of Public Schools	A series of exams used to challenge high achieving learners who have considerable experience in both solving highly challenging problems and writing proofs.

Canada, for example, runs a science essay writing competition, where learners are encouraged to write about a specific science topic such as the environment, energy and food. This competition also helps the learner to read and learn more about the literature and practical aspects of STEM subjects[4]. Exciting competitions such as hosting games where learners compete for cash and prizes by answering multiple choice STEM questions can be broadcasted as a game show on national television and thereby stimulate an interest in STEM far beyond the participants in the competition. Learners in the United States of America, for example, also compete by submitting a two-minute video about a particular topic which can describe a new innovation or solution to an everyday problem[5].

[4] See http://usascholarships.com/the-dupont-challenge-science-essay-competition/ for more information
[5] See https://www.youngscientistlab.com/challenge for more information.

Teachers in China are provided with training offered by national coaches so they can prepare the contestants for Olympiads and competitions. The training of coaches, teachers and learners has made a great impact on the mathematics performance of learners in China. The competitions provide a challenge to both teachers and learners; yet they are also an opportunity to explore non-routine problems that will provide growth and learning and recognise problem solvers (Bin & Yee, 2007). An analysis of the table shows that most countries offer science competition activities to the higher performing learners indicating that there is an agenda to grow the quality of the top performing students.

Participating in academic competitions can have a positive impact in the enhancement of science learning on the learners (Kuech and Sanford, 2014). There are at least 10 ways that academic competitions have been found to enhance learning (see Figure 1).

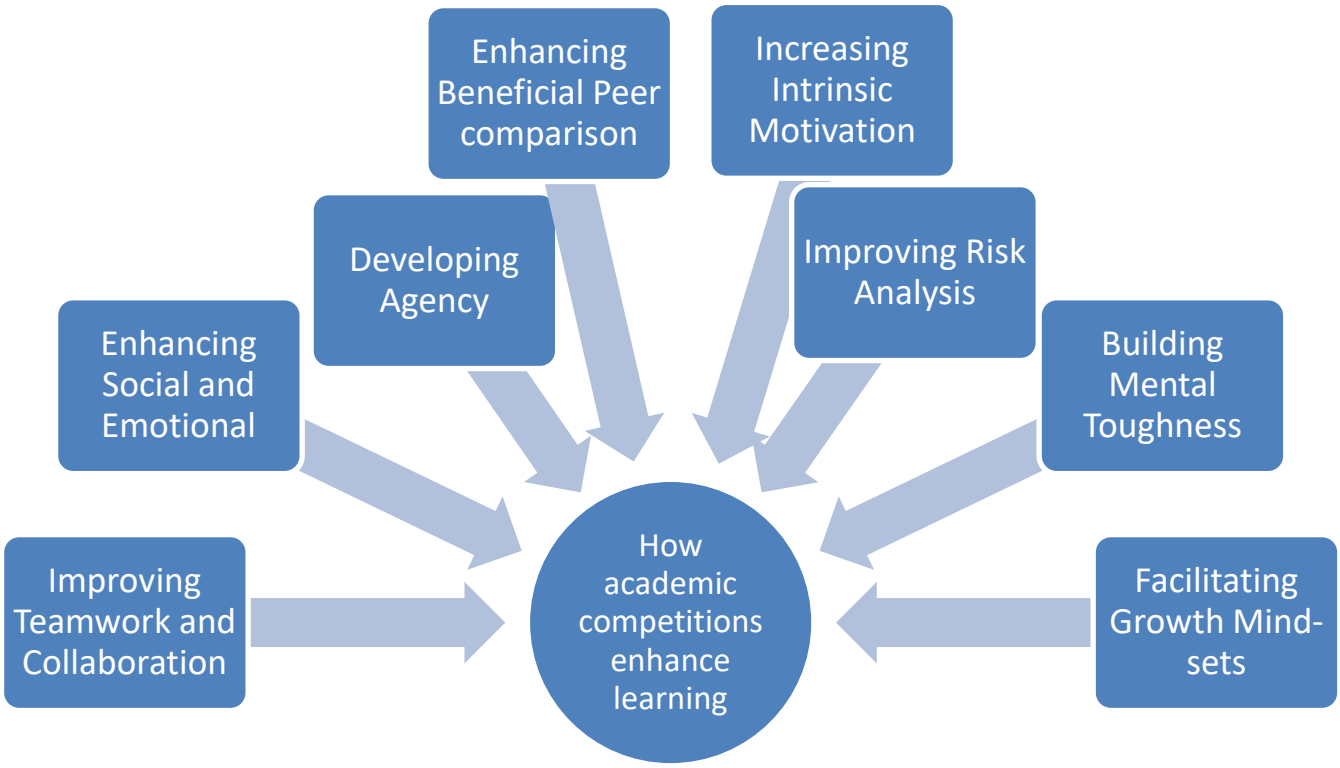


Figure 1: The connective factors produced by academic competitions to enhance learning

Improving Teamwork and Collaboration

Most team-based educational competitions require learners to take on challenging tasks that require good communication, collaboration, teamwork and enthusiasm (Thrasher, 2008). Well-structured, consciously designed competitions especially foster collaboration and team work. The combination of intergroup competitions with intragroup cooperation provides the benefits of teamwork and collaboration simultaneously, noting that most real life situations combine both competitive and cooperative aspects (Opsal, 2013). Teamwork in competitions is beneficial as it helps in making the team members work harder at understanding their specific skills and how to work well with one another as they are striving to accomplish a challenging task together (Kuech and Sanford, 2014).

Enhancing Social and Emotional Learning

Social and emotional learning is the process of acquiring core competencies to recognise and manage emotions, set and achieve positive goals, appreciate the perspectives of others, establish and maintain positive relationships, make responsible decisions, and handle interpersonal situations constructively (Clarke et al., 2015). Enhancing social and emotional skills in youth is also a critical strategy for improving mental capital and contributing to social development. Competitions play a role in supporting the social and emotional development of young people and in enabling them to achieve their potential (Clarke et al., 2015). It is through competitions that learners are able to encounter and learn to successfully deal with differing viewpoints as they manage to work together with widely varied personalities.

Developing Academic Heroes

Academic heroes are idols (who are experts in a certain academic field) that learners look up to for academic inspiration and interest in learning. Developing ‘academic heroes’ involves teaching learners to be goal orientated by presenting them with obstacles to overcome; having a clear set of guidelines; and having a clear timeframe for completion of challenging tasks. These competences help to ensure consistent and effective participation in academic competitions. A number of learners report that participating in competitions was a key contributor to the level of engagement they achieved, as they valued these competitions as external motivation (O’Leary, 2010).

The learners also felt that incentives such as awards accelerated the process of learning as learners were more inclined to participate.

Increasing Intrinsic Motivation

When used correctly, competitions can motivate learners to actively engage in classroom discussions and take ownership of their learning outside of the classroom (O'Leary, 2010). Academic competitions with the ultimate objective of having learners develop sufficient intrinsic motivation can help children acquire work habits for sustained accomplishment. The competitive aspect thus provides the initial motivation which can be a catalyst for learners to discover the enjoyment and excitement of being deeply involved in learning. Extrinsic motivation enhances interest and involvement, particularly when learners are given positive, informative feedback on their work. Motivation for learning, class participation and entering competitions is also accelerated through the introduction of an additional incentive (for example prizes for best entries and peer recognition) even more so than the use of formative assessment alone (Ediger, 2001).

Enhancing Beneficial Peer Comparisons

Part of the increased levels of achievement and productivity may be due to an increase in teamwork and study skills promoted by the participation in academic competitions (Kuech and Sanford, 2014). When gifted learners observe the superior work of other gifted children, they tend to develop healthy perspectives on themselves and their competitors. They learn to respect the quality of work of other children and accurately assess their own performance in light of the performance of their intellectual peers. They achieve an accurate assessment of where their level of performance stands in the world of their intellectual capacity and, in turn, develop a more wholesome self-concept (Ozturk and Debelak, 2008).

Developing Agency

Academic competitions require of learners the skills of studying, analysing, and effectively managing challenges independently (Kuech and Sanford, 2014). It is a testament to the resilience of youth, as well as their proclivity toward challenge, that stimulates the sense of productivity and growth (Kuech and Sanford, 2014). These

competitions can be an academically and psychologically enriching process (Kuech and Sanford, 2014; Thrasher, 2008).

Strengthening Academic Self-Concept

Strengthening academic self-concept may be one of the most important aspects of academic competitions that cannot be easily provided to learners in a normal classroom environment (Kuech and Sanford, 2014). Being thrust into a situation where the participant must cope with failure (even after they prepared and did their best), can promote the development of a learner's self-awareness. For example, learning to fail and being able to cope with the self-esteem and emotional aftermath. Academic competitions may provide the type of environment that causes learners to reflect on their knowledge and abilities and self-evaluate their image, promoting improved personal growth and development for the participants (Kuech and Sanford, 2014).

Facilitating a Growth Mind-Set

Competitions can offer the types of experiences that foster the development of productive attitudes and work habits (Kuech and Sanford, 2014). They also can nurture emotional and psychological growth. Mathematics competitions are useful for strengthening the education of gifted learners; moreover teachers of the gifted can provide mathematics that is dynamic, innovative, and creative. Mathematics competitions for elementary, middle, and high school learners are used to explore problem-solving and real-life applications (Kuech and Sanford, 2014).

Building Mental Toughness

Competitions can teach learners how to handle stressful and competitive situations. Resiliency and determination builds the mental toughness for learners to persist in the learning experience even after anxiety and undue stress (Kuech and Sanford, 2014; Davis and Rimm, 2004). Some learners seem to need to compete with others in order to push themselves to produce at a higher level.

Improving Risk Analysis

Children can develop new strengths in the wake of an emotionally difficult experience, especially when they have access to a caring adult's support and guidance (Ozturk and Debelak, 2008). There are a number of negative side effects of extreme

competitiveness, including excessive anxiety and stress (Kuech and Sanford, 2014), however it is also evident that if all competitions were removed some learners would lose their incentive to learn (Opsal, 2013). Competitions can also inspire outstanding achievement and productivity, and can earn the competitor desirable attributes such as resilience. Preparations for competitions provide opportunities for learners to explore non-routine problems which are not usually encountered as a part of the regular curriculum (Thrasher, 2008).

As illustrated in this section, there is a variety of ways in which competitions contribute to learning and learner achievement and the promotion of STEMI. They include improving teamwork and collaboration among learners, enhancing social and emotional learning, developing academic heroes, increasing intrinsic motivation, enhancing beneficial peer comparisons, developing agency, strengthening learners' academic self-concept, facilitating a growth mind-set, building mental toughness and improving risk analysis. We now turn to the methodology and findings of this study.

3. Methodology

Data collected through surveys followed up with a few interviews were used to answer the research questions. Mixed methods research is most appropriate because it provides a more complete view of the phenomenon under study (Creswell, 2014). As part of the preparation for data collection, ethical clearance was applied for and approved by the Human Sciences Research Council's Research Ethics Committee.

The strategies used for sampling included a combination of purposive and snowballing sampling. Some of the participating organisations were identified and approached at the STEMI Olympiads and Competitions Community of Practice Conference held in Pretoria in March 2017. From these organisations, snowballing was used to identify further organisations, as the present organisations knew of and could refer the researcher to other organisations who also hosted STEMI Olympiads or competitions in South Africa. A total of 15 organisations that were identified and approached to participate in the study. However, only 13 of these organisations gave consent to participate in the study. Information for the other two organisations were collected through reports extracted from the internet. All the organisations that volunteered to

participate in the study were informed of the purpose of the study and assured that the research would not bring any harm (see Table 1 below for the list of participating organisations).

A survey instrument was developed and used for data collection. The survey comprised of questions that related to the organisation's role in the Olympiad and competition, their implementation and outcomes. We uploaded the survey to an online software program called *SurveyGizmo* and e-mailed the link to the organisations for completion.

After the surveys had been completed by the participants, the quantitative data was analysed using Microsoft Excel producing various figures and tables. In order to help develop and inform some of the unclear and unexpected results of the quantitative component, the researcher then conducted telephonic interviews with six of the participants of the survey. The interview questions were mostly related to the challenges that organisations encountered while implementing the competitions. The results of the follow-up interviews were documented and coded into themes as part of the analysis. The results from both the analyses were combined and are presented below.

The five sections that follow set out the findings of this study. The findings are grouped according the main research questions set out earlier.

4. FINDING 1: Which organisations are involved in STEMI Olympiads and competitions in South Africa?

The characteristics of the fifteen organisations that participated in the study varied in terms of how long each programme has been active and the type of activities administered by the different organisations. The timeline below of when these South African organisations became involved in Olympiads and competitions illustrates the long history of STEMI Olympiads and competitions in the country.

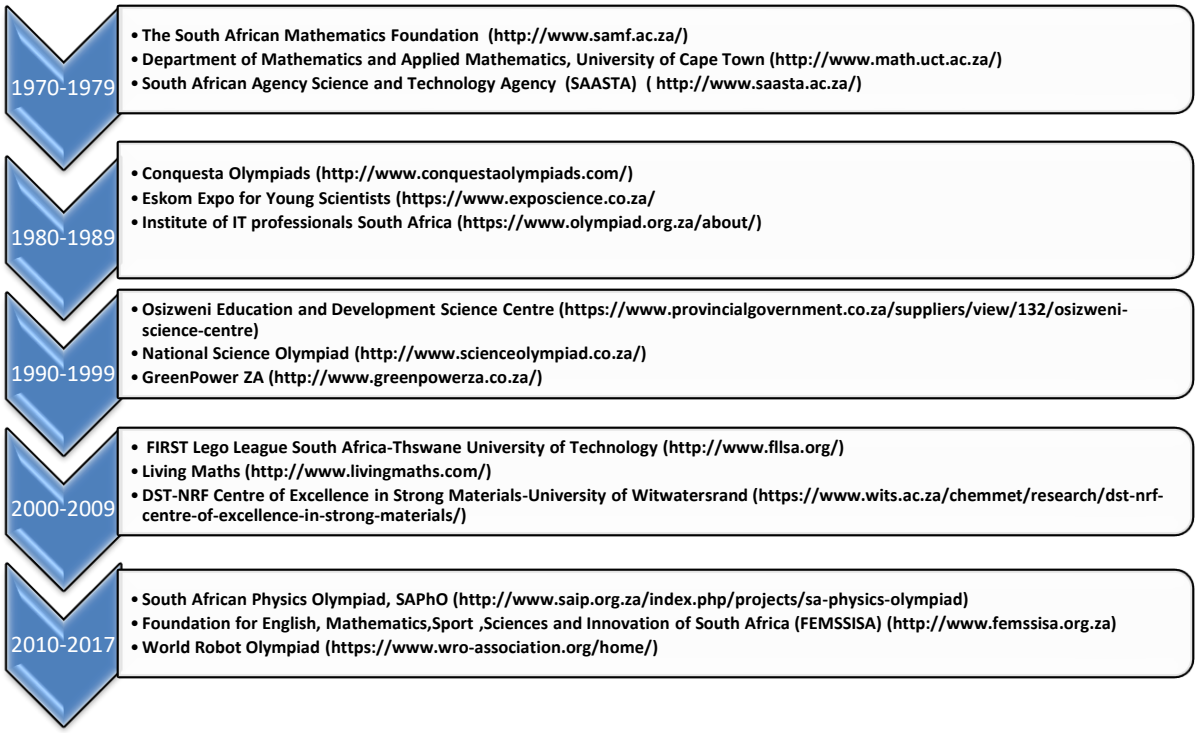


Figure 2: Timeline of the introduction of the fifteen organisations

5. FINDING 2: What is the size and scope of the STEMI Olympiads and competitions?

We determined the size and scope of STEMI Olympiads and competitions by examining: (i) the learners targeted by each organisation; (ii) the number of learners that participated between 2014 and 2017; age and grade of learners (iii) the provincial distribution of activities.

Targeted learners

All the participating organisations targeted schools of all school types/quintiles, in rural and urban areas, to participate in their competitions. *Living Maths* reported that 80% of the learner participants were from fee-paying schools, while 20% were from no-fee schools. Most of the organisations reported that they targeted all learners within schools, both boys and girls of all population groups, except for one organisation, i.e. the *South African Physics Olympiad*, which only targeted high achievers. Table 2 sets out the target groups and specific focus of the participating organisations.

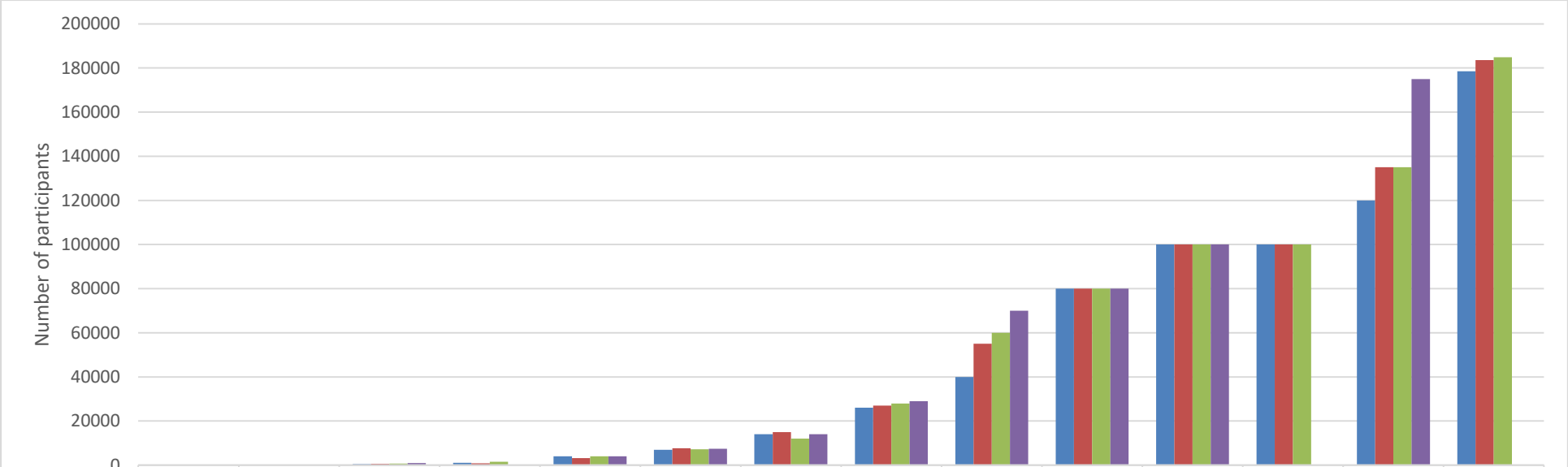
Table 2: Organisations, target groups and focus

Name of organisation	Target group	Focus	School type	Gender	Learners targeted	Urban/ rural areas	Fee charged
Conquesta Olympiad	Grade 1-9	Mathematics, Science	All	Boys and girls	All learners	Both	Yes
Department of Mathematics and Applied Mathematics, University of Cape Town	Grade 7-12	Mathematics	All	Boys and girls	All learners	Both	No
DST-NRF Centre of Excellence in Strong Materials-University of Witwatersrand	Grade 10-12	Science	All	Boys and girls	All learners	Both	No
Eskom Expo for Young Scientists	Grade 6-12	Science, mathematics, computer science, technology, engineering	All	Boys and girls	All learners	Both	Yes
Foundation for English, Mathematics, Sport ,Sciences and Innovation of South Africa (FEMSSISA)	Grade 1-12	Mathematics, Science	All	Boys and girls	All learners	Both	Yes
First Lego League robots competition	Grade 1-9	Science, Technology, Engineering	All	Boys and girls	All learners	Both	Yes
GreenPower ZA	Grade 2-12	Engineering, technology	All	Boys and girls	All learners	Both	Yes
Institute of IT professionals South Africa	Grade 4-12	Engineering, Technology	All	Boys and girls	All learners	Both	No
Living Maths Olympiad	Grade 1-9	Mathematics	All	Boys and girls	All learners	Both	Yes
National Science Olympiad	Grade 4-12	Science	All	Boys and girls	All learners	Both	Yes
South African Agency Science and Technology Agency (SAASTA)	Grade 4-12	Science	All	Boys and girls	All learners	Both	Yes
Osizweni Education and Development Science Centre	Grade 7-12	Science	All	Boys and girls	All learners	Both	No

South African Mathematics Foundation	Grade 4-12	Mathematics	No-fee paying, fee paying and independent schools (All)	Boys and girls	All learners	Both	Yes
South African Physics Olympiad (SAPho)	Grade 10-12	Science	All	Boys and girls	Only high achievers	Both	No
World Robot Olympiad	Grade 4-12	Science, Engineering, Technology	All	Boys and girls	All learners	Both	Yes

Number of participating learners

Each of the participating organisations reported hosting varying numbers of learners between 2014 and 2017. The organisations established more recently had the least number of learners participating in their competitions, while those that were established earlier had gained more participants over the years. Over 2.1 million learners participated in these activities over the period (see Figure 3).



	DST-NRF Centre of Excellence in strong Materials - University of Witwatersrand	South African Physics Olympiad	World Robot Olympiad	First Lego League robots competition	Osizweni Education and Development Science Centre	Department of Mathematics and Applied Mathematics, University of Cape Town	National Science Olympiad	Institute of IT professionals South Africa	South African Agency Science and Technology Agency (SAASTA)	Conquesta Olympiad	Eskom Expo for Young Scientists	Foundation for English, Mathematics, Sport ,Sciences and Innovation of South Africa	South African Mathematics Foundation	Living Maths Olympiad
2014	50		500	1106	4000	6948	14000	26000	40000	80000	100000	100000	120000	178471
2015	50	69	575	865	3200	7694	15000	27000	55000	80000	100000	100000	135000	183592
2016	50	154	720	1572	4000	7176	12000	28000	60000	80000	100000	100000	135000	184923
2017	50	260	950		4000	7399	14000	29000	70000	80000	100000		175000	

Figure 3: Number of participants for each organisation, 2014 - 2017[6]

[6] Figures for the ESKOM Expo for young scientists were extracted from reports found on the internet. Figures for the GreenPower ZA participants could not be found online. There were no figures available at the time of the study for the 2017 First Lego League Robots competition, FEMSSISA and Living Maths Olympiad. The South African Physics Olympiad did not start until 2015.

Provincial spread

The South African map below (Figure 4) shows the number of organisations that are targeting learners in each of the provinces. The Western Cape and Gauteng provinces have the highest number of competitions and activities, while the Free State and North West provinces have the least number of competitions and activities.

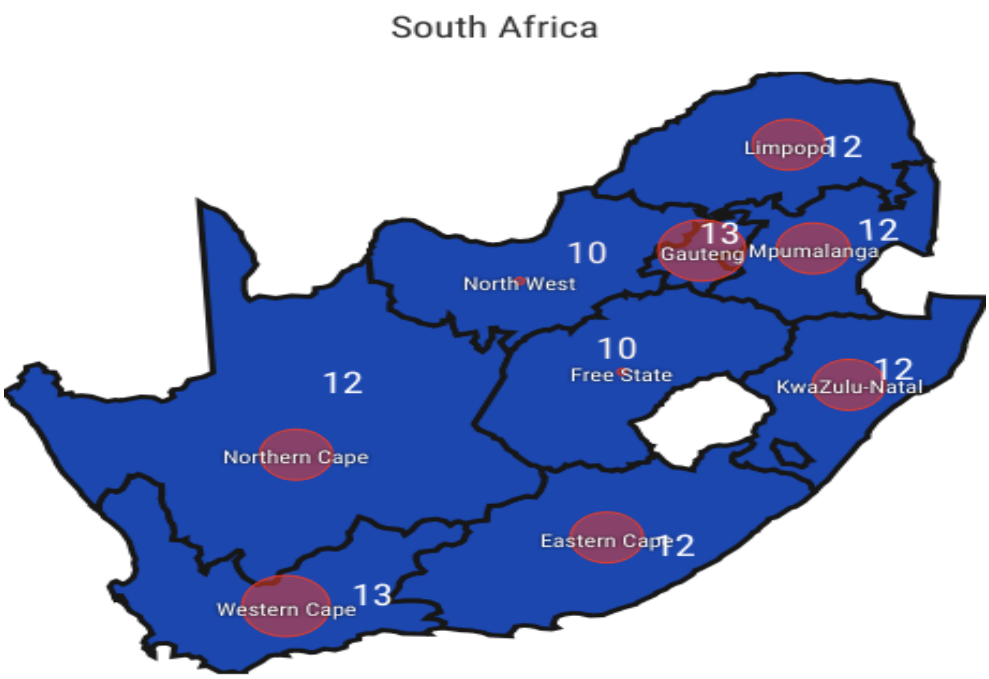


Figure 4: South African map illustrating the number of organisations targeting each province

Two issues arising from the survey were identified as requiring further investigation in qualitative interviews. The first relates to the reasons for the increase in learner participation over the period, and the second relates to the targeting of learners in rural areas. These issues will be discussed in turn.

Possible causes of increases in the number of participant over the years

The number of participants in the Olympiads or competitions has increased over the years for many of the organisations. The organisations were asked about the possible reasons for this change over time.

Increased marketing through sending school invitations, consistent follow-ups and increased funding (thereby making the first round free) were emphasised as key factors that contributed to an increase in participation. Below are quotations from the interviews with participating organisations, which illustrate the reasons for increased participation. Perhaps if these were emphasised further, a further increase in learner participation can be achieved.

Follow-ups made to the schools and teachers also help to increase the participation. Sending several reminders really helps. Good communication with the schools is important

Making the first round to be free

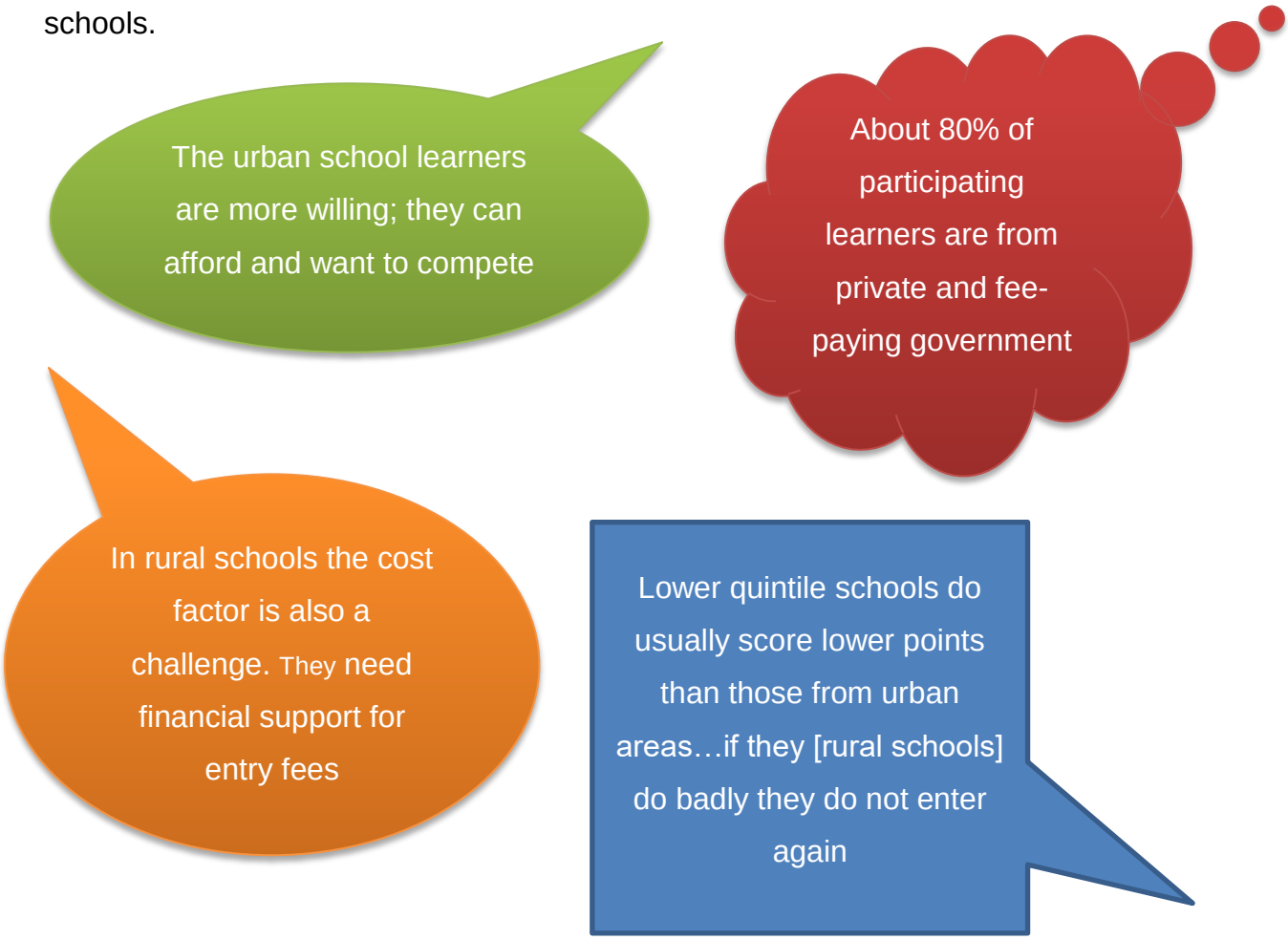
We have a large international group that also takes part in the competitions through the internet

When the subject advisors and other stakeholders help to promote the competitions in schools, an increase in the participation is usually observed that year

Teacher development is a strategy that is lacking in rural schools. If the teachers have an interest and are properly developed they [teachers] will also influence the learners to be interested

Rural vs urban school participation

Almost all organisations indicated that there is greater interest in participating in the Olympiads and competitions from urban schools than from those schools in rural areas. This is due to a number of factors, including the costs involved in entering these competitions, which many rural schools are unable to afford. Learners from rural schools also often perform poorly compared to learners from urban schools, and thereafter do not enter the competitions again. The lack of teacher development was also highlighted, as teachers that are interested and have the necessary knowledge and skills can inspire learners to take part. Some of the competitions are completed online and therefore learners require access to the internet to participate; which in most cases automatically excludes learners from rural areas as they often do not have access to the necessary technology to participate. The following quotations from the organisations highlight the greater extent of participation by learners from urban schools.



6. FINDING 3: What are the types of activities and assessments done in the Olympiads and competitions?

The organisations conduct a range of activities for learners, including debates, competitions, and quizzes. Table 2 provides a list of the various activities and their descriptions as provided by the respondents. Learners participate in these activities as individuals or as part of a team.

Table 1: Activities conducted by the organisations

Activities	Description
Contests	These are tests that are held at a smaller scale than Olympiads
Debate	A formal discussion in which opposing arguments on a particular topic are put forward and usually end with a vote
Expos	A public show that shares scientific investigations and engineering projects
Maths games	A form of competitive activity played according to rules, strategies, and outcomes are defined by clear mathematical parameters
Model Building	Learners compete by physically building models
Olympiads	Formal, written examinations which are conducted at a large scale
Programming	Learners compete by analysing, developing and generating algorithms (also referred to as coding) on a computer
Quiz	These are brief written or oral assessments to measure growth in knowledge, abilities and skills
Speech	Speaking and doing presentations, related to a particular topic mostly in front of a group of people

Just over a quarter (28%) of the organisations hosted Olympiads; while 36% hosted contests. Programming, speeches, debates and quiz competitions were among the activities that were administered by the fewest organisations. Table 3 summaries the different types of activities and how these activities were carried out by each organisation.

Table 2: Type of activities and how they are carried out

Name of organisation	Type of Activity	Question format	Graded by	Venue
Conquesta Olympiad	Olympiads	MCQ	Testing organisation	In school
Department of Mathematics and Applied Mathematics, University of Cape Town	Olympiads, contests	MCQ, essay, short answers	Testing organisation	Out of school
DST-NRF Centre of Excellence in Strong Materials	Contests	Project and challenge-based (posters)	Judges	Out of school
Eskom Expo for Young Scientists	Expos	Project and challenge based	Judges	Out of school
FEMSSISA NPC	Olympiads, contests, model building, debates, expos, maths games	MCQ, short answers	School teachers	In and out of school
First Lego league robots competition	Olympiads, contests, model building, speech, expos, programming	Project and challenge based	Volunteers	In and out of school
GreenPower ZA	Expos	Project and challenge based	Judges	Out of school
Living Maths Olympiad	Olympiads	MCQ, short answers, fill-in-the-blank	School teachers	In and out of school
National science Olympiad	Olympiads	MCQ	Testing organisation	In schools
NRF/SAASTA national science Olympiad	Olympiads, debates, quiz	MCQ, project and challenge based	Judges	In school
Osizweni education and development science centre	Contests, model building, expos	Project and challenge based	Judges	In and out of school
South African physics Olympiad (SAPho)	Olympiads	MCQ	Testing organisation	In school
The South African Computer Olympiad	Olympiads, contests	MCQ, short answers, write programs, fill-in-the-black	Online automated software, teachers	In and out of school
The South African Mathematics Foundation	Olympiads, contests	Multiple Choice Questions (MCQ), short answers	Testing organisation and school teachers	In and out of school
World Robot Olympiad	Olympiads, contests, model building, expos	Project and challenge-based	Judges	In and out of school

Figure 5 elaborates on the types of activities showing their prevalence. It shows that contests and Olympiads are the most frequently conducted activities, followed by expos and model building. Less prevalent formats are: Maths games, programming, quizzes, speeches and debates.

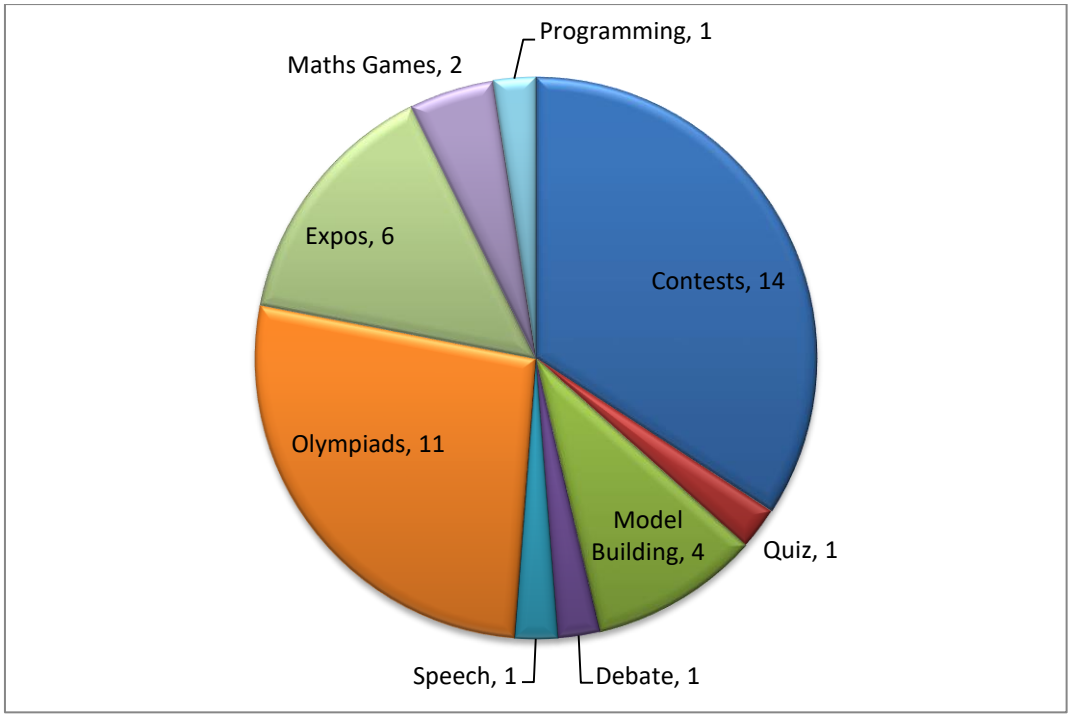


Figure 5: Type of activities administered by the organisations

Figure 6 illustrates the prevalence of different format of questions that is used in the different activities. The organisations indicated that most of the questions asked in the Olympiads or competitions are Multiple Choice Questions (45%) and short answer questions (25%). The least common question types are essays and writing programs.

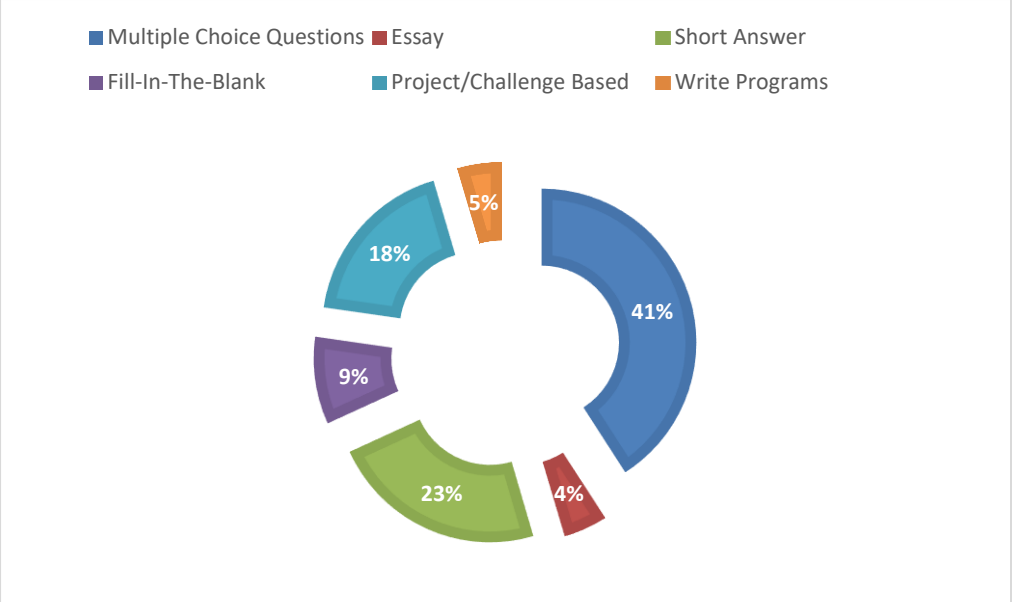


Figure 6: Percentage of each competition question type

Content areas covered in the Science competitions

Most of the science competitions covered Mathematics, Mechanics, sound and light, science in society, general science, electricity and magnetism, as well as indigenous knowledge amongst others. The coverage of topics in the science competitions is shown in Figure 7.

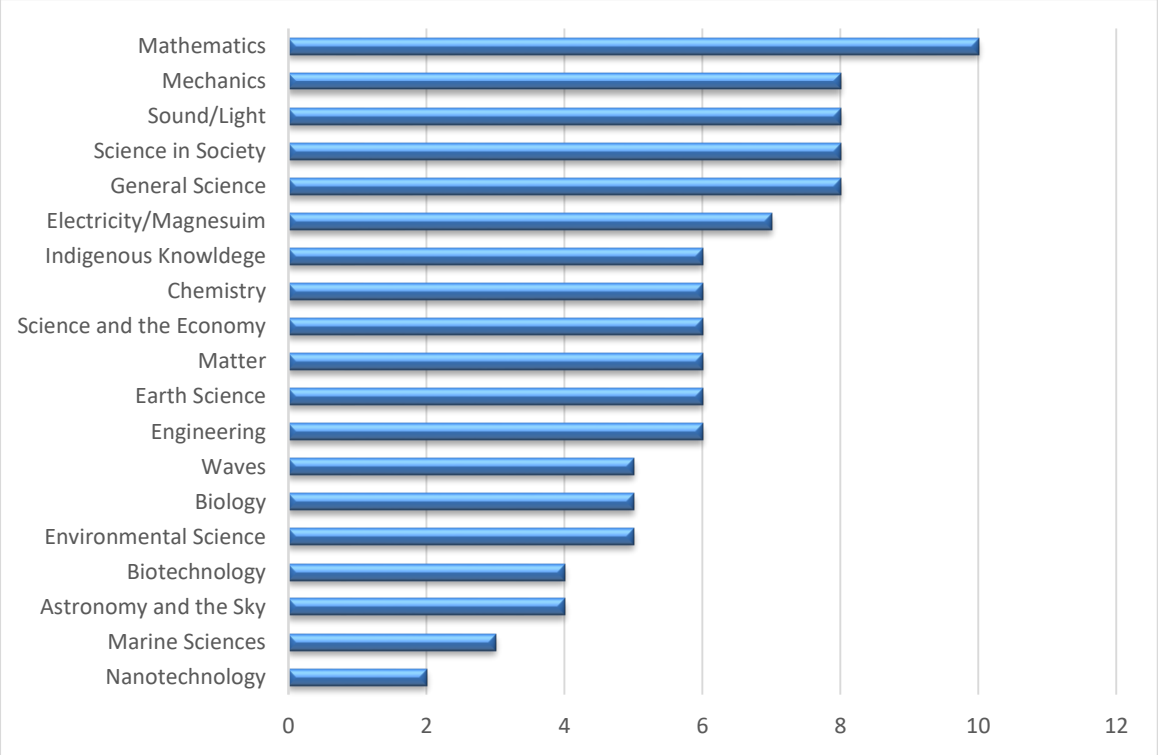


Figure 7: Number of organisations covering particular science competition content areas

Content areas covered in the Mathematics competitions

The coverage of different content areas in Maths competitions is shown in Figure 8. Most prevalent are measurement, data handling and probability, followed by geometry, patterns/functions/algebra, and numbers/operations/relationships.

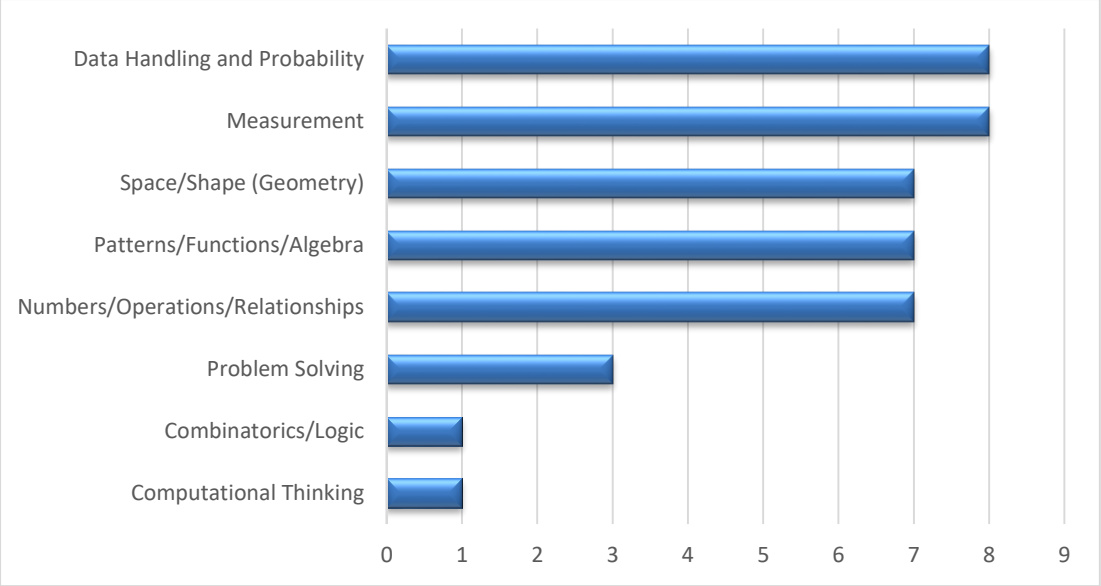


Figure 8: Number of organisations covering each mathematics competition content area

7. FINDING 4: What are the incentives of the STEMI Olympiads and competitions to participants?

Most of the organisations give the participating learners tokens for participation and provide rewards for the top achievers. Most organisations give learners certificates and awards of participation. Rewards also include cash prizes/vouchers, prizes like laptops, tablets or calculators, and/or trips. The least common form of reward is funds for participating schools. Figure 9 indicates the number of each type of reward offered by the organisations.

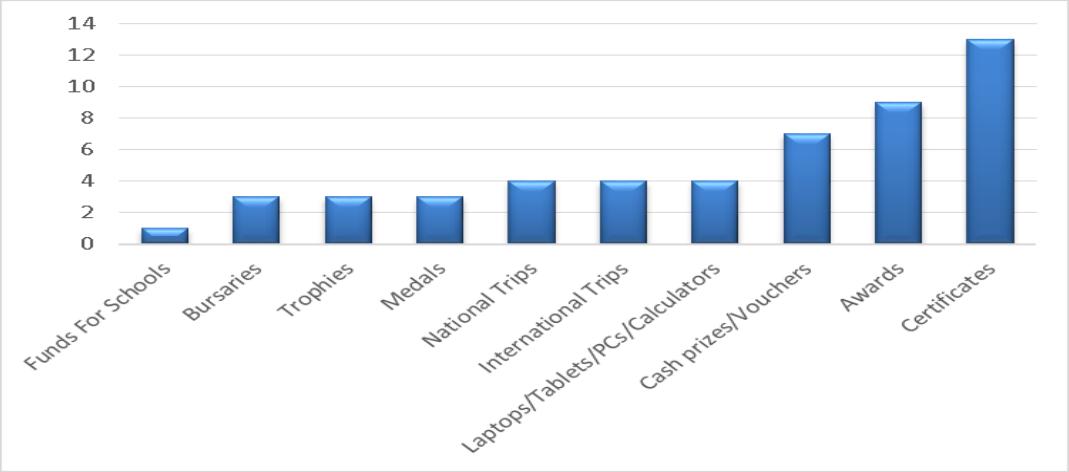
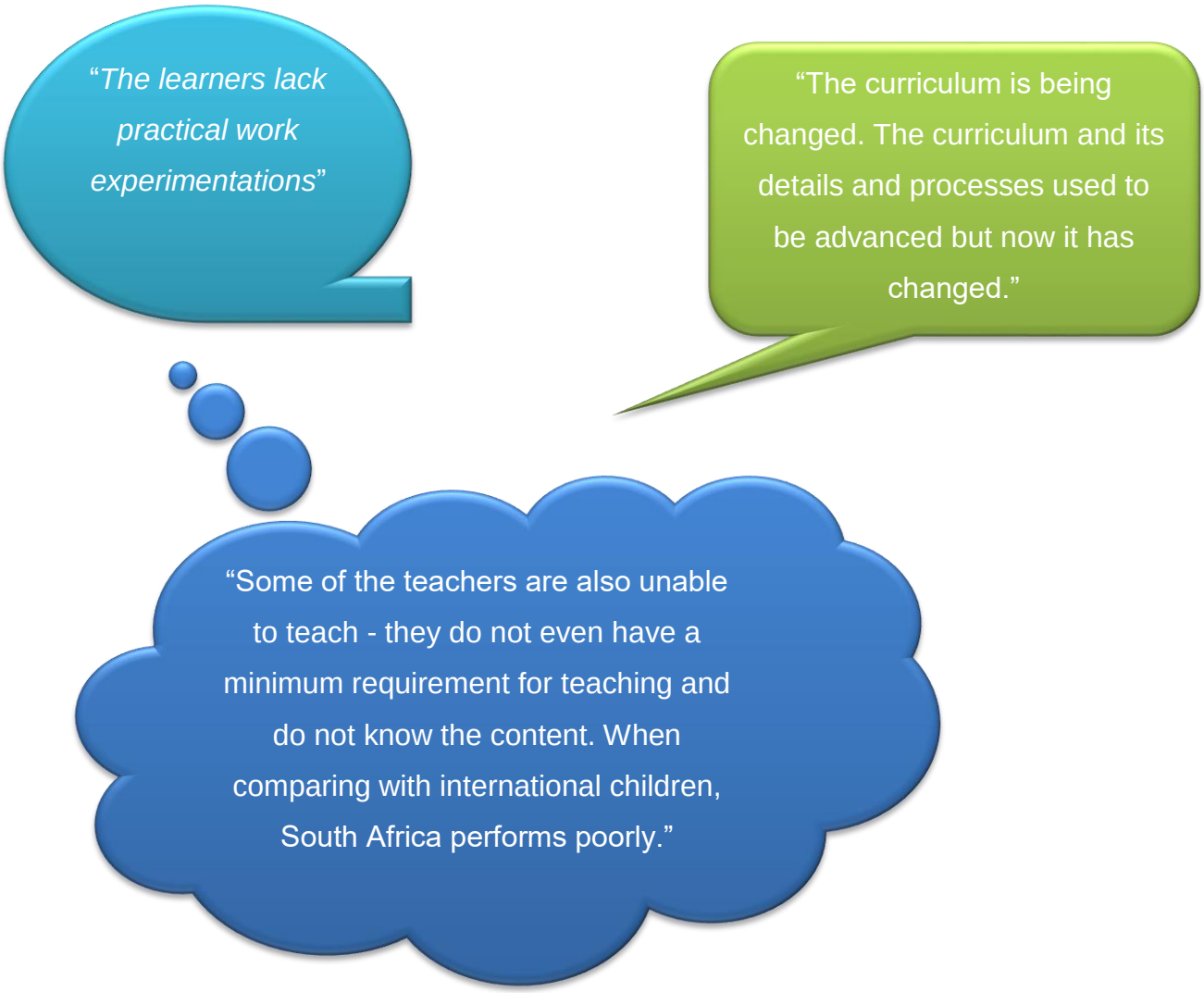


Figure 9: Number of different rewards offered by the organisations

8. FINDING 5: Challenges encountered by the organisations in achieving their objectives

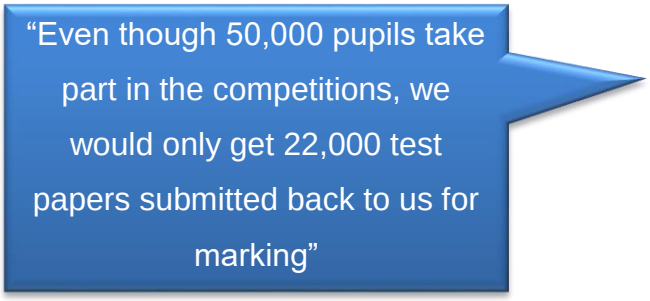
Interviewees mentioned a variety of challenges that their organisations encountered in achieving their objectives. They highlighted the following to be the main challenges in relation to their four key objectives, i.e. enhance learners' understanding of maths and science; identify and nurture talent; expose a target number of learners to maths and science outside of school; and advance learners' critical thinking skills. The challenges are highlighted using (anonymised) quotations from some of the respondents.

Firstly, the interviewees talked about the fact that learners were struggling to get a better understanding of maths and science because of a lack of well-trained teachers, curriculum changes or lack of practical work.

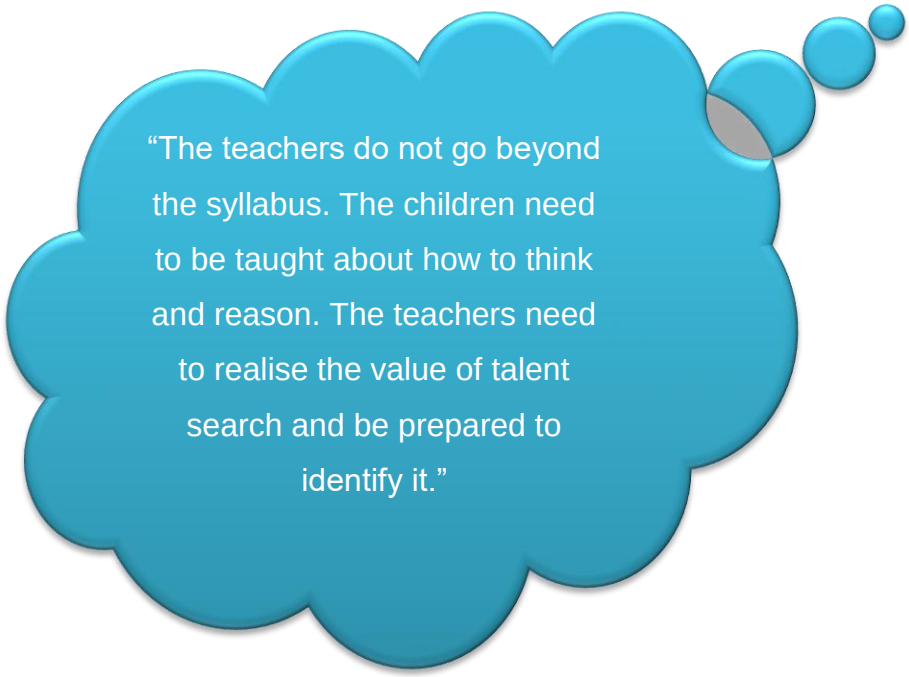


The participants also shared the difficulty they experience in their attempts to identify and nurture talent:

Some organisations indicated a low response rate:



The learners' critical thinking skills are also said to be held back because teachers teach to the syllabus and do not identify (and encourage) talented learners:



9. FINDING 6: How can learner participation be expanded?

The interviewees also shared a number of ways in which learner participation and achievement in science competitions can be improved. The recommendations below have been categorised to address the different stakeholders and topics.

Recommendations for the Department of Science and Technology and the Department of Basic Education

- Support Olympiads and competitions by assisting in the distribution of invitations and entry forms to schools;
- Sponsor revision material for schools and learners e.g. robot sets, competition elements, challenge platforms, and so forth.
- Sponsor entry fees for learners from no-fee schools.
- Promote an interest in STEM subjects through various in and out of school activities.
- Promote Olympiads and competitions as an exciting way of learning STEM.
- Encourage innovative competing strategies such as sending of a video or an audio (rather than a pen-and-paper test) that describes how an everyday problem can be solved using maths and science.
- Promote a televised maths and science competitive gameshow. This will help in getting other learners interested in maths and science.
- Pay attention particularly to schools in rural areas to ensure that they are aware of these competitions, have the financial support to participate and are interested in participating.
- Encourage and promote dedicated trainers for those learners participating in the maths and science competitions.
- Encourage that competitions are translated to the learner's home language.

Recommendations for provincial education departments

- The provincial education departments need to play a role in promoting participation in STEMI Olympiads and competitions amongst the schools in their provinces, and;
- Be involved in searching for talented learners and ensuring that teachers are prepared and encourage learner involvement.

Recommendations for teachers

- Understand the value of STEMI Olympiads and competitions how they facilitate the development of learners;
- Explain to the learners the significance of the Olympiads and competitions and inspire the learners to participate, emphasising the importance of applying knowledge and developing reasoning skills to the learners;
- Introduce the tests to learners and conduct practice rounds before the actual competition;
- For those competitions that require teachers to grade the performance of the learners, teachers need to participate and allocate some of their time to be trained to carry out the necessary tasks such as grading test sheets;

Recommendations for subject advisors

- Subject advisors should encourage schools to participate in the maths and science competitions.

Recommendations regarding training

- The establishment of national and provincial centres for general re-training and up-skilling of teachers and learners in STEM-related subjects

Recommendations regarding communication

- A more effective e-mail database system is needed comprising of all schools that are eligible for participation in Olympiads and competitions, and;
- Follow-ups need to be done when communicating and reminding the schools and teachers about each of the competitions.

Recommendations regarding competition promotion

- Visits by the hosting organisations may be beneficial, particularly to non-participating schools;
- Teacher meetings and conferences provide a platform to promote the competitions, and;
- Promotion in news media (e.g. television and newspapers) contributes to creating publicity around the competitions.

Recommendations regarding the identification and tracking of learners

- A database of learners that are high achievers in STEM subjects should be established, which allows them to be monitored and supported over time.

10. Conclusion

The aim of this study has been to map the current landscape of STEMI Olympiads and competitions in South African schools. The results of the study give an overview of the size and scope of the STEMI Olympiads and competitions that are being organised across the country: the organisations involved, the targeted schools and learners, the spread of activities across different provinces, the types of activities and assessment tasks involved, the content areas that are being covered, and the rewards that are provided to participating learners and schools.

It shows that there is an uneven spread of Olympiads and competitions across different geographical areas (with a concentration in urban areas and particularly in Gauteng and the Western Cape Province), and the need to target more activities at foundation phase learners. The review of literature on the benefits of participation to learners shows that competitions should be introduced to learners at a young age (Grade R), where they are made to be a fun and enjoyable activity for young children to participate in; mini-competitions can even be introduced before formal schooling to get pre-schoolers used to it and stimulate their curiosity in STEM-related matters early on. As indicated in the report, competitions are a good way of learning with numerous benefits to the participants.

While all school types, school locations, and school levels are targeted by the various organisations, the research shows that not all participate in equal numbers in the competitions. In particular, there appears to be less interest in rural schools to participate in the competitions. A number of reasons were mentioned to account for this. The expansion and promotion of maths and science competitions across the country, but especially in the non-urban schools, can therefore usefully draw on the results of this study as well as specific recommendations presented in its final part.

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