State of readiness for digitisation of Science Olympiads and competitions in South Africa

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List of Acronyms and abbreviations

4IR	Fourth Industrial Revolution
AIC	Australian Informatics Contest
AIO	Australian Informatics Olympiad
ASTEMI	Association of Science, Technology, Engineering, Mathematics and Innovation
CAPS	Curriculum and Assessment Policy Statement
CAT	Computer Applications Technology
COVID-19	2019 novel CoronaVirus Disease
CSE	Computer Science and Engineering
DBE	Department of Basic Education
DHET	Department of Higher Education and Training
DoE	Department of Education
DSI	Department of Science and Innovation
DST	Department of Science and Technology
FET	Further Education and Training
FIRST	For Inspiration and Recognition of Science and Technology
GEAR	Get Excited About Robotics
GMMDC	Govan Mbeki Mathematics Development Centre
ICT	Information and communication technology
iGeo	International Geography Olympiad
IOI	International Olympiad in Informatics
I-SET	Inspired towards Science Engineering and Technology
IT	Information Technology
NEIMS	National Education Infrastructure Management System
NGO	Non-Governmental Organization

NRF	National Research Foundation
OBR	Brazilian Robotics Olympiad
REC	Research Ethics Committee
SA	South Africa
SAASTA	South African Agency for Science and Technology Advancement
SAGTA	Southern African Geography Teachers Association
SANGO	South African National Geography Olympiad
SAPhO	South African Physics Olympiad
SES	Science Engagement Strategy
SPEAR	Sigma Public Education and Research
SSAG	Society of South African Geographers
STEM	Science, Technology, Engineering, and Mathematics
TBM	Techno-Blended Model
TIMSS	Trends in International Mathematics and Science Study
YiSS	Youth into Science Strategy

Executive summary

One of the objectives of the Department of Science and Innovation (DSI) is stimulation of a culture of science in the schooling system. Olympiads and competitions are important, as they expose learners from diverse contexts to the practical nature of science. As the information and digital age continues to unfold, Olympiads and competitions in many countries are moving towards digitisation. This provides additional benefits to participation in Olympiads and competitions, such as introducing advanced critical thinking and computer literacy skills among school-going children. Evaluating the state of readiness of the organisations and users to digitise science Olympiads and competitions is an important step towards the development of such interventions. This report provides some responses to this evaluation using results from the following:

1) a survey completed by eight of the current science Olympiads and competitions host organisations,
2) five national case studies,
3) interviews with three ICT experts, and
4) an overview of international literature.

Results from the survey indicate the views of the organisations currently hosting science Olympiads and competitions in relation to pursuing these activities digitally, to what extent they pursue these activities digitally, their current state of digitising, their future plans in digitising, the resources they anticipate as being required and the anticipated outcomes of digitising or not digitising in the South African context. The interviews from the five national case studies revealed important lessons, which are presented. Interviews with three information and communication technology (ICT) experts also outlined the practical steps to make implementation of digital activities possible, the resources and infrastructures absolutely necessary to implement digital Olympiads for both the organisations and the users, the estimated timeframes and financial implications, and finally the anticipated challenges and ways of navigating these.

Through triangulation of these data sources, overall a hybrid approach (comprising both paper-and-pencil and digital, either online or offline) to implementing digital science Olympiads and competitions in South Africa was recommended. It was emphasised that there is no single approach which can be taken to implement a digital science Olympiad or competition within the

South African context. Rather, planning and implementation depend on infrastructure and the features of the activity itself.

Therefore, in moving forward digitisation needs to be viewed on a spectrum and implemented accordingly. For example, some organisations may want to host their Olympiad or competition entirely online, whereas others may want to use digitisation in their administration and to offer certain materials online, but retain a face-to-face event. This would require differential levels of digitisation to suit the requirements of the organisation. For organisations moving towards digitisation, alignment across the DSI-Department of Higher Education and Training and Department of Basic Education can create a strategy policy for the transition of Olympiads and competitions from pen-and-paper to digital format, development of a data centre, and development of a shared platform. This will create a coherent framework within which organisations and schools can participate effectively, especially if the goal is mass participation.

Other requirements for digitisation include the necessary technological infrastructure, hardware, and software, which may include a data centre, devices and access to connectivity, and personnel such as an ICT professional or developer, data manager, and administrator. Sponsors can play a meaningful role regarding these requirements, by providing: (i) assistance with software or platform development, management of the project, development of the test items, and marketing; (ii) assistance with equipment, venues, human resources, or finances; (iii) human capital; and (iv) assistance with provision of data. Universities and their staff and students are exceptionally rich sources of expertise who can assist in several ways, most particularly by asking their ICT students and graduates to aid in the development and implementation of digital Olympiads and competitions.

In conclusion, technology should be perceived as an enabler of the learning process, rather than as a silver bullet solution. In order to use technology for science Olympiads and competitions, solutions must be tailored to suit the readiness of the host institutions, schools and their learners to adopt the technology. There is no ‘one-size-fits-all’ solution which can cover the huge diversity inherent in the South African context. Furthermore, all solutions must be designed with cognizance of resource and infrastructural constraints. A holistic view is essential and needs to incorporate multiple levels in creating solutions. The mere provision of hardware and software is very likely to fail.

Contents

1 Introduction

The Department of Science and Innovation (DSI) has been working with several organisations and associations to promote awareness and create interest in Science, Technology, Engineering, and Mathematics (STEM) subjects at both primary and secondary school level. Science Olympiads and competitions are one way in which STEM subjects are promoted and popularised in South Africa. While these Olympiads and competitions do not necessarily lead directly to any career benefits, they do provide an initial intellectual stimulus to learners:

- Firstly, the Olympiads and competitions enrich the school educational curriculum, and the presented problems provide intellectual provocation and uncommon opportunities for the teaching and learning of STEM subjects.
- Secondly, participation may be the impetus to a later career in a STEM area and to undertake a lifelong journey into the realms of exciting intellectual challenges.
- Lastly, the Olympiads and competitions aim to identify learners who may have an aptitude for STEM subjects.

The main aims of Olympiads and competitions are thus to promote interest in the STEM subjects, inspire excellence in STEM education, and discover talent among school-going learners. Bearing these aims in mind, burgeoning technological innovation, encapsulated by ‘digitisation and machine learning’, leads us to evaluate what this could mean for Olympiads and competitions. New ways of participation alongside new ways of teaching, both using a range of technologies, can enable learners to be trained appropriately for the future digital world (DSI, 2019).

As the information and digital age unfolds, Olympiads and competitions in many countries are transitioning to digital platforms. Digitisation is the process of converting information from a physical format into a digital one which allows Olympiads and competitions to be hosted digitally. This provides additional benefits – and possible exclusions – to participation in Olympiads and competitions. For example, the digitisation of Olympiads and competitions advances critical thinking and computer literacy skills among school-going children and has the potential to reach a wider range of learners – if they have the resources to access online sources. Furthermore, digitisation can become a catalyst to the effective tracking and monitoring of learners (South African Agency for Science and Technology Advancement [SAASTA], 2018).

While we need to keep in mind possible negative consequences, it may be beneficial to South Africa to be able to embrace this trend, both to capitalise on these benefits and to continue to compete on a global scale. Establishing the possibility of whether this can be done requires an understanding of the Olympiads and competitions currently offered in South Africa, their readiness to digitise, the requirements of digitisation, and the current rates of learner participation and performance.

This research thus establishes the state of readiness of host organisations and participants for digitisation of science Olympiads and competitions in South Africa. This research inquiry forms part of the DSI's Science Engagement Strategy (SES), which incorporates the Youth into Science Strategy (YiSS). These strategies aim to enhance participation, performance and awareness of science and science-based careers among school-going youth and undergraduates in STEM subjects (Department of Science and Technology [DST], 2014). Furthermore, the YiSS aims to produce a high number of quality science-, engineering- and technology-inclined high school leavers through cultivating science and technology awareness and literacy, and through engaging more school learners and undergraduates to awaken interest in pursuing careers in STEM subject fields.

This venture of establishing the state of readiness for digitisation of Olympiads and competitions in South Africa forms part of Strategic Aim 1 of the SES, with the objective "to popularise science, engineering, technology and innovation as attractive, relevant and accessible in order to enhance scientific literacy and awaken interest in relevant careers." This aim communicates the need for science education support and implies that Olympiads and competitions can enable learners to refine and display their own understanding of scientific knowledge and techniques acquired from the formal classroom (through the Department of Basic Education [DBE]) (DST, 2014, 2015).

1.1 Problem statement

Several Olympiads and competitions are currently conducted in South Africa, most via the traditional pen-and-paper system. There are 17 independent organisations and two government-based organisations involved as organisers in South African science Olympiads and competitions (DST, 2018). The number of learners who take part in Olympiads and competitions has increased markedly, with a recent report showing that approximately 600 000 learners per year participated in the 2014–2017 period (Figure 1) (Zulu, Juan, & Luescher, 2018). A multiple-choice format is frequently used, but project and challenge-based assessment tasks, short answer or essay-based assessment, quizzes, speeches and debates, model-building competitions, programming competitions, and expos are also included.

These science Olympiads and competitions may be adjudicated by external judges, educators, the organization involved, or automated software, and activities are held in school or both in and out of school (Zulu et al., 2018). Some of these local Olympiads and competitions also have direct or indirect international legs, where national winners get an opportunity to compete against their counterparts from other countries. How digitisation could both positively and negatively impact the administration and activities offered by these organisations needs to be explored, as well as what would be required in order to digitise.

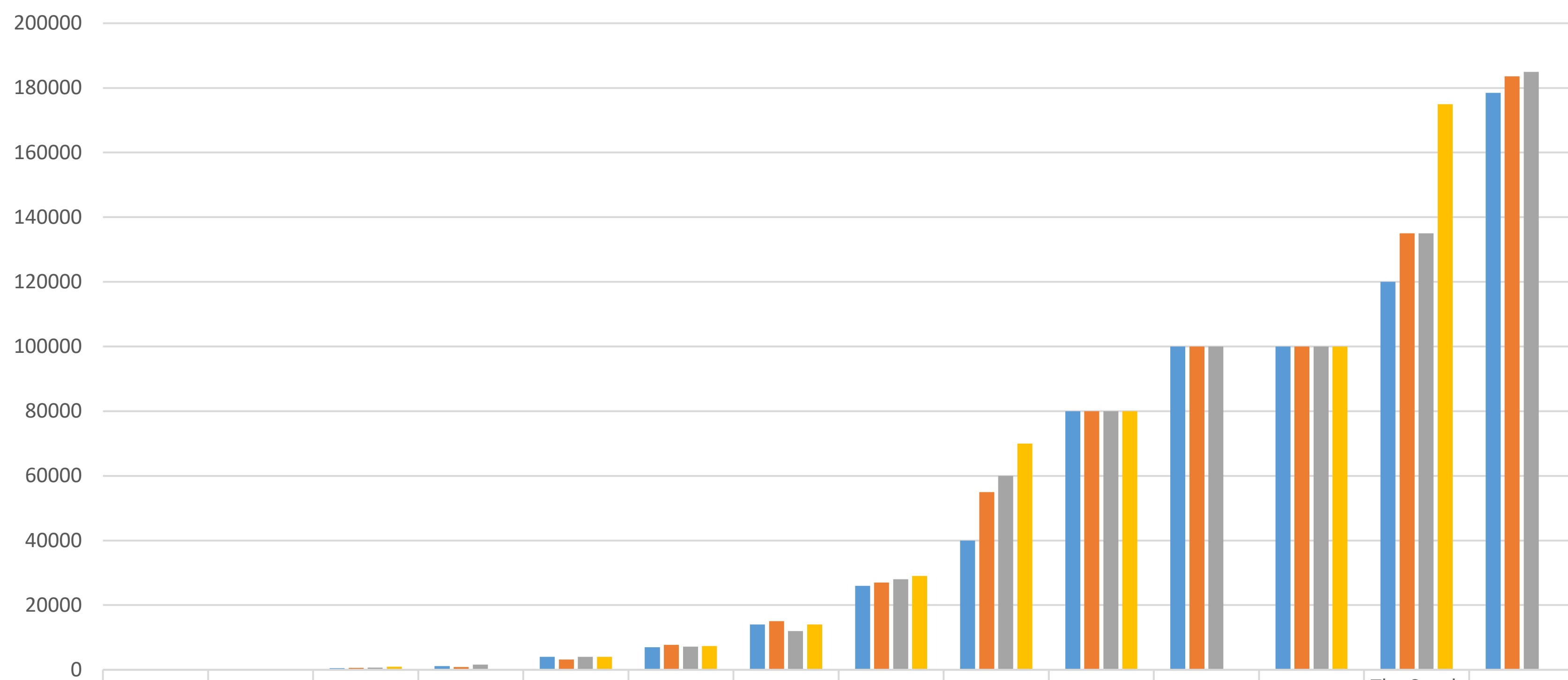
Regarding what is needed in order to digitise, the general resources and infrastructure that are required must be established. There are common elements, such as laptops or similar devices, and network connectivity which are necessary for all digital activities. However, there are also requirements which are unique to the South African context due to the 'digital divide' within our society. Some individuals are able to move forward in terms of technological advancement, such as exposure to telecommunication (means of electronic transmission of information over distances), but others are not. This is related to inequalities within South African society, where a lack of resources and infrastructure is still a challenge in numerous geographic locations, particularly rural spaces. In addition, according to the Poverty Trends report for 2006 to 2015 (Stats SA, 2017), 55.5% of the South African population is living in poverty. These factors have the potential to undermine efforts and innovation, as some schools, educators, and learners – arguably those who need access the most – may be excluded. This needs to be kept in mind when exploring the digitisation of Olympiads and competitions, particularly to ensure that digitisation is not carelessly adopted.

The wide range evident in the level and availability of information and technology communication (ICT) infrastructure in South African schools – the digital divide – has meaning for the introduction, setup and implementation of Olympiads and competitions. For example, Merry, Gallotta, and Hultquist (2008) reflected on the impact of this phenomenon on implementation of the South African Computer Olympiad. In brief (this Olympiad organiser was interviewed during the current study and details are given later), the organisers instituted three rounds of the Olympiad, with the first round not requiring a computer. The second round does require a computer, but printout submissions of source code and test runs were accepted in order to incorporate learners without access to a computer (Merry et al., 2008). This shows that when ICT infrastructure is not available, out-of-the-box solutions are necessary to ensure equal and fair participation.

Schools which do have ICT infrastructure have alternative options to ensure participation. In 2016 the Social Sciences Provincial Olympiad was hosted at Glenanda Primary School for all Grade 6 and 9 learners in Gauteng province. Learners answered a series of history and geography questions, which the software system immediately marked. All learners used the desktop computers and Internet connection in the school ICT laboratory (Gauteng Department of Education [DoE], 2016). These two examples illustrate the two ends of the spectrum with regard to ICT provisioning and that different solutions may need to be offered, depending on the context.

Resource and ICT requirements also link to participation rates in the digitised Olympiads and competitions. It is noted that participation in the Olympiads and competitions offered is still exceptionally low, with only about 19% of the 13 million learners in South African public schools taking part each year (DST, 2018). Considering the aforementioned aims and benefits, increasing participation in these Olympiads and competitions (held either digitally or using paper and pencil) is a worthwhile goal. It needs to be established whether these rates of participation would improve or worsen if digitisation is effected.

This research evaluated the readiness and related requirements for digitisation of science Olympiads and competitions currently being hosted in South Africa. It also established the potential impact of digitisation on learner participation and performance rates.



	DST-NRF Centre of Excellence in Strong Materials	South African Physics Olympiad	World Robot Olympiad	TUT FIRST Lego League	Osizweni Science Centre	UCT mathematics competition	NATIONAL SCIENCE OLYMPIAD	South African Computer Olympiad Trust	SAASTA	Conquesta	FEMSSISA NPC	Eskom Expo	The South African Mathematics Foundation	Living Maths
2014	50	0	500	1106	4000	6948	14000	26000	40 000	80000	100 000	100000	120 000	178 471
2015	50	69	575	865	3200	7694	15000	27000	55 000	80000	100 000	100000	135 000	183 592
2016	50	154	720	1572	4000	7176	12000	28000	60 000	80000	100 000	100000	135 000	184 923
2017	50	260	950	0	4000	7399	14000	29000	70 000	80000	0	100000	175 000	0

Figure 1: Current host organisations and participation numbers

1.2 South African policy and context

As noted in the *White Paper on e-Education* (DoE, 2004, p. 8): "a global revolution is currently taking place in education and training". This document notes that the use of ICT is becoming increasingly prevalent, and is crucial for both learning and work in the twenty-first century (DoE, 2004). However, the White Paper also acknowledges that there is a digital divide within South Africa which presents barriers to the educational benefits of technology. We must therefore take cognizance of the profile and distribution of ICTs in schools. Here we will consider connectivity and computer availability in schools.

In 2016 a draft technical report was released by the National Education Collaboration Trust titled *The Status of ICT in Education in South Africa and the Way Forward* (Meyer & Gent, 2016). The authors highlighted the fragmented approach to the introduction of ICTs in South African schools with unequal concentrations across provinces and quintiles. The fragmented implementation is due to, firstly, policy and strategy being defined at a high level rather than at all levels of the education system, and developed without context-specific differentiation; and secondly, lack of clear guidelines and integrative strategies, which results in implementation being driven by the objectives of the provider, which differ in each instance (Meyer & Gent, 2016). The fragmentation was also shown by the National Education Infrastructure Management System (NEIMS) report (DBE, 2019), which indicated a wide discrepancy in connectivity and available computers across schools (Figure 2).

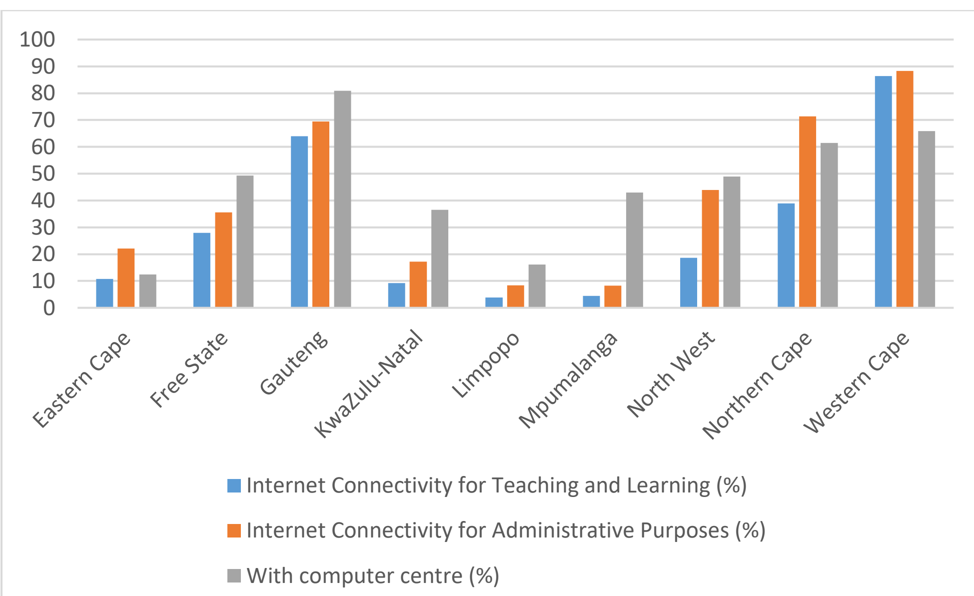


Figure 2: NEIMS Aug. 2019 report: School connectivity and computer centre percentages by province

The NEIMS report revealed, for example, that Mpumalanga reported that 4% of schools had Internet connectivity for teaching and learning, compared to 86% reported by the Western Cape (DBE, 2019). This same discrepancy is present in homes. The General Household Survey 2018 showed that access to the Internet at home was highest among homes in the Western Cape (25.8%) and Gauteng (16.7%) and lowest in Limpopo (1.7%) and North West (3.0%) (Stats SA, 2018). There is still a digital divide across South Africa, both in schools and in homes, which will have an impact on how digitisation of Olympiads and competitions takes place.

Background information collected during the Trends in International Mathematics and Science Study (TIMSS) 2015 (National Center for Education Statistics, 2016) provides further depth regarding the relationship between socio-economic status and access to connectivity. Learners who attended no-fee and fee-paying schools were less likely to have Internet connectivity at home than their peers who attended independent schools, for both Grade 5 and Grade 9 learners (Figure 3).

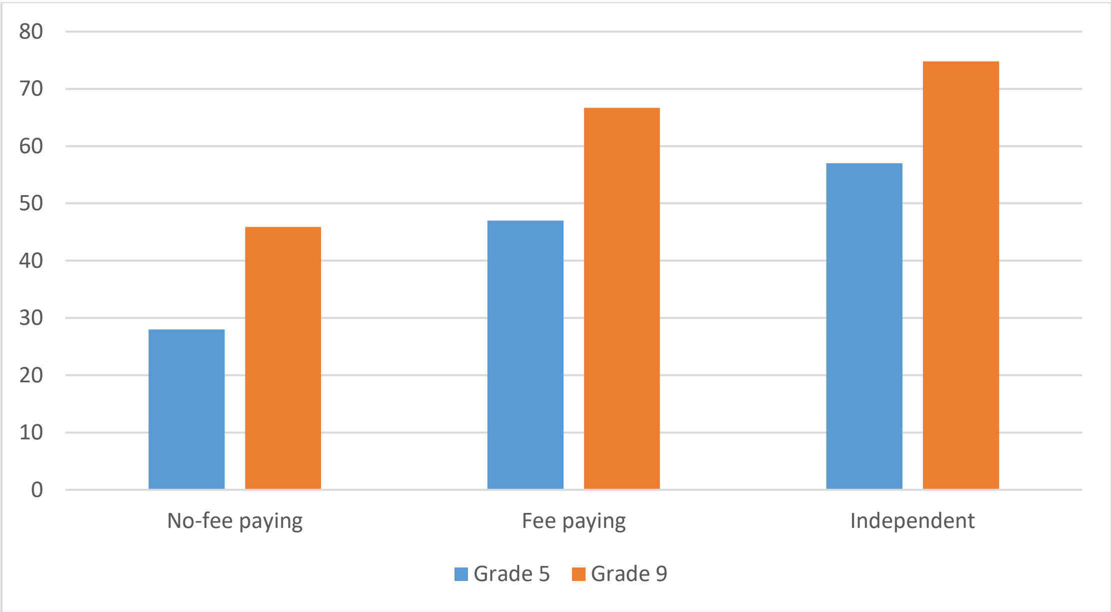


Figure 3: TIMSS 2015 data regarding home connectivity

This context has implications for the current study. While the importance of digitising Olympiads and competitions is evident, this cannot be undertaken at the expense of learners from under-resourced areas. The solutions which are identified will therefore bear this in mind.

2 Methodology

Data were collected through a survey questionnaire and semi-structured, in-depth interviews and international review. A mixed-methods research approach was considered appropriate as it provides a more complex 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 (Protocol No. REC 1/19/06/19).

A combination of purposive and snowballing sampling was used. Firstly organisations were identified through referral by the DSI as well as at the Association of Science, Technology, Engineering, Mathematics and Innovation (ASTEMI) and Provincial Co-ordinators Meeting held on 4–6 March 2020. From these organisations, snowballing was used to identify further organisations. Experts in the field of ICT were identified through referral. Both a survey instrument (questionnaire) and semi-structured interview schedules were developed and used for data collection, their development being guided by multi-level lenses of macro-, meso- and micro-perspectives.

The survey instrument comprised questions that related to each organisation's perspective of digitisation, its role in Olympiads and competitions in South Africa, the requirements for digitisation, and the roles of the various stakeholders. The survey was uploaded to Google Docs and the link was emailed to the identified organisations for completion. The quantitative data received were analysed using Microsoft Excel to provide figures and tables. The qualitative data were thematically analysed.

Questions in the semi-structured interviews with eight organisations centred on how digitisation is currently used or not used in implementation of the science Olympiad or competition. Insights into the requirements for digitisation were also gained. Questions in the interviews with three ICT experts focused on how digitisation is initiated and maintained, and the costs thereof. These data were documented and coded into themes as part of the analysis.

3 Results

This section presents the results from the survey responses, the national case studies, the ICT expert interviews, and an international literature review. The results gained from the survey responses are presented first. Eight organisations participated in the survey: FIRST Robotics, Living Maths, National Zoological Garden, South African Mathematics Foundation, South African National Geography Olympiad, SPEAR Development Foundation, World Robot Olympiad, and Virtual GEAR. One of these organisations had two respondents, giving a total of nine. The respondents are coded as O1A, O1B, O2, O3, etc.

3.1 Insights from online survey responses

All eight organisations reported that they targeted both urban and rural areas, with one noting *"Being online allows us to reach both urban and remote rural schools"* (O5). All school phases and types of schools are targeted, with two organisations also including educators and tertiary students (Figures 4 and 5).

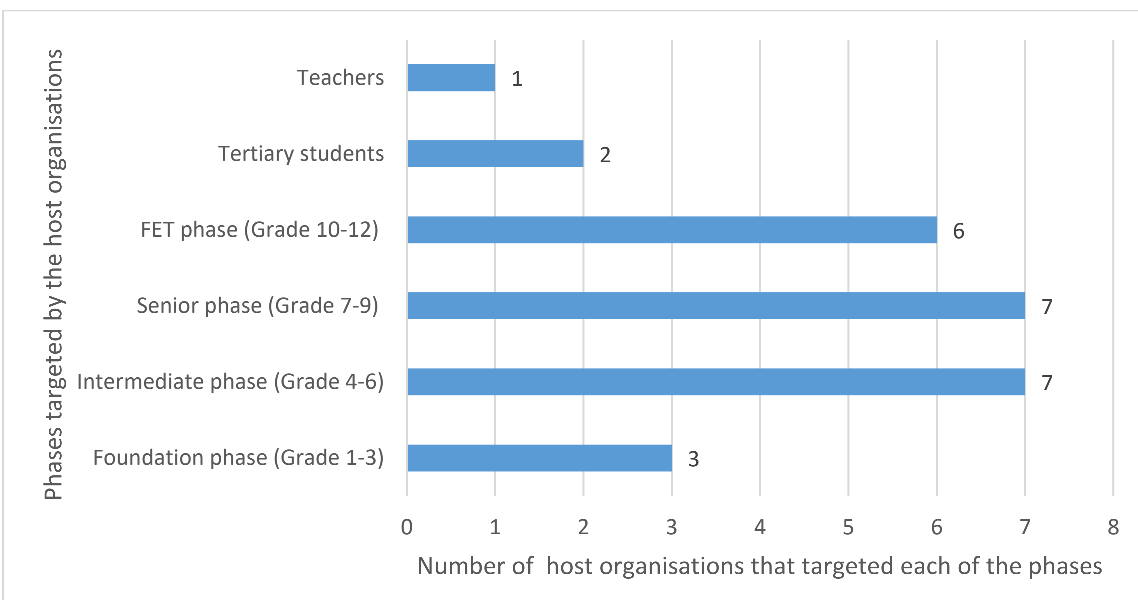


Figure 4: Education phases targeted by host organisations

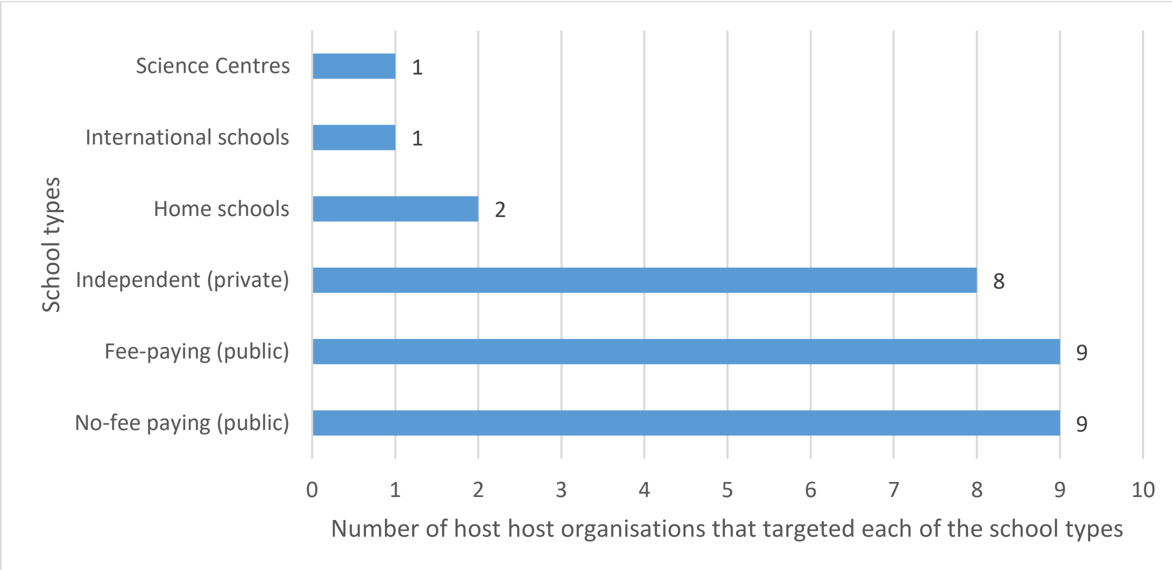


Figure 5: School types targeted by the survey respondents

3.1.1 What is understood by the term 'digitisation'?

The organisations indicated several features of digitisation which contribute to our understanding of this term. Most of the respondents stated that digitisation refers to making content available in a digital manner, i.e. on desktops, tablets, and smartphones, as well as online, i.e. via the Internet. They referred to the development of content specifically for digital use, as well as the conversion of hard copy content into a digital format. Respondents also identified another key aspect of digitisation; using available technologies to facilitate the administration and management of the Olympiad or competition:

> "*When traditional practices like teaching, examination, consulting, delivery, training, etc., are done through a digital medium. When a traditional approach is swapped for a digital approach, e.g., text books, examinations, Olympiads, etc."* (O7)

3.1.2 Should we pursue digitisation in South Africa?

All nine survey respondents indicated that we should pursue the digitisation of Olympiads and competitions in South Africa. Their reasons for supporting this shift centred on progression, keeping up with global technological innovation and the fourth Industrial Revolution (4IR), and to expand the reach and impact of their activities. For example, digitisation has the ability to *"simplify distribution of information and sharing"* (O2), which *"makes for more efficiency, better for the environment, quicker turnaround time to process results and send certificates"* (O7). Related to the latter, digitisation is characterised by quick delivery and readily provides metrics regarding participation and performance. Many of the organisations indicated that embracing digitisation would allow them to equip both educators and learners better as well as to enable self-development for both. This is particularly important for learners who will ultimately be entering a *"digital workplace"* (O4). It was also stated that *"after the initial costs of setting the competition, the costs to take part should be lower if any at all"* (O7).

Some organisations noted that cognizance needs be taken of the challenges of social inequality in South Africa, with limited resources and infrastructure for many schools, educators, and learners:

> *"Without losing sight of the social inequality in SA, it is nevertheless necessary to explore (and implement) new technology. As organisers we need to develop our systems to be ready and to answer the needs of the learners who are equipped."* (O1A)

Given these challenges, it was put forward that the relevant authorities must provide connectivity for all learners, so that they have opportunities for access to knowledge and gaining technological skills. This was furthermore related to the COVID-19 pandemic, which has highlighted the need for Internet access for learning and for bridging social distance.

3.1.3 To what extent is digitisation possible for South African Olympiads and competitions?

Most respondents reported that digitisation would only be partially expressible in the South African context due to difficulties in accessing data and basic computer facilities. The respondents indicated that these challenges, and other difficulties meant that the majority of learners are not equipped to take part in digital Olympiads and competitions, with one organisation estimating that 60–70% of school learners would be **unable** to participate (O1A). This organisation elaborated, using their currently pen-and-paper based Olympiad as an example:

> *"... although it is possible to do the Olympiad on a desktop, this has a lot of logistical issues for schools. If it can be made available on smartphones, more learners could have access"* (O1A)

They did add the caveat that using smartphones has its own set of issues, but did not elaborate or state whether these were related to accessibility or technology. These difficulties in accessing data and facilities are related to social inequality:

> *"[digitisation is] possible to most urban schools but could be problematic to some of the most rural schools"* (O1B)
>
> *"A large percentage of the independent schools and private schools would be able to participate. A large percentage of our outreach schools won't have the resources"* (O7)

Two digital competition organisations noted that the nature of their activities required face-to-face contact. This implies that there is a difference between implementing digital Olympiads and digital competitions.

For example, the first organisation stated that face-to-face contact was integral to their activity as it involves building models on-site. However, the respondent went on to note that *"some preparation for the challenges and research can be done in the digital domain"* (O2). As an example:

> *"Virtual models can be built as preparation but cannot replace the actual experience of touch and feel of the real hardware. The digital building environment makes it easier since all parts are readily available in libraries and there is no simulation of human error in the virtual environment"* (O2).

This organisation thus highlighted a key benefit of using digital resources: allowing learners the opportunity for additional practice and the ability to further their learning at their own pace. The second organisation made a similar point but returned to the limitations brought by social inequality in that *"virtual platforms are in development which would still require computers/tablets and a WiFi point to download coding software"* (O4).

3.1.4 How is digitisation currently used by South African Olympiads and competitions?

Figure 6 indicates the digitisation methods currently used by South African Olympiads and competitions with regard to their administration, learning content provision, and interactive learning. The latter includes participation in their Olympiad or competition. The figure also indicates methods planned for future use, which are discussed in the next section.

The majority of organisations noted that they use digitisation for administration purposes such as online registration, online payments, email, and social media. In terms of online registration a variety of digitisation methods were reported, including email, Google Drive, and WhatsApp. One organisation indicated that they are using online registration but would also like to use this digitisation method in the future. They explained this by reflecting on the iterative nature of implementing a digital method, where errors found in the field must be fixed and another field test done (this is discussed further in section 3.4 regarding insights from ICT experts):

> *"Online registration and payment was implemented over two years as some problems only arose during the process. A third year will be necessary to complete the process. An external developer is used"* (O1A)

Organisation 1A also utilises a website, video teaching via YouTube, social media including Facebook, Twitter, and LinkedIn, Google Drive, and makes materials – including training manuals and past papers – available for download on the website. They make use of email and Skype for normal office operations. In terms of the human resources required, an external developer was used for development of both the online registration and payment and the website. The YouTube account used for their videos was paid for by their affiliated university. They have an internal media officer who co-ordinates their social media presence. This organisation thus makes extensive use of digital methods, and shows that a network of professionals is required.

Two organisations were able to show how their digitisation methods contribute to creating a community of learning, one of them stating:

> *"Part of the* [Organisation] *core values is to share what you have learned. This resulted in a huge platform of free resources for teams to tap into. This includes animations, tutorials, videos, etc."* (O2)

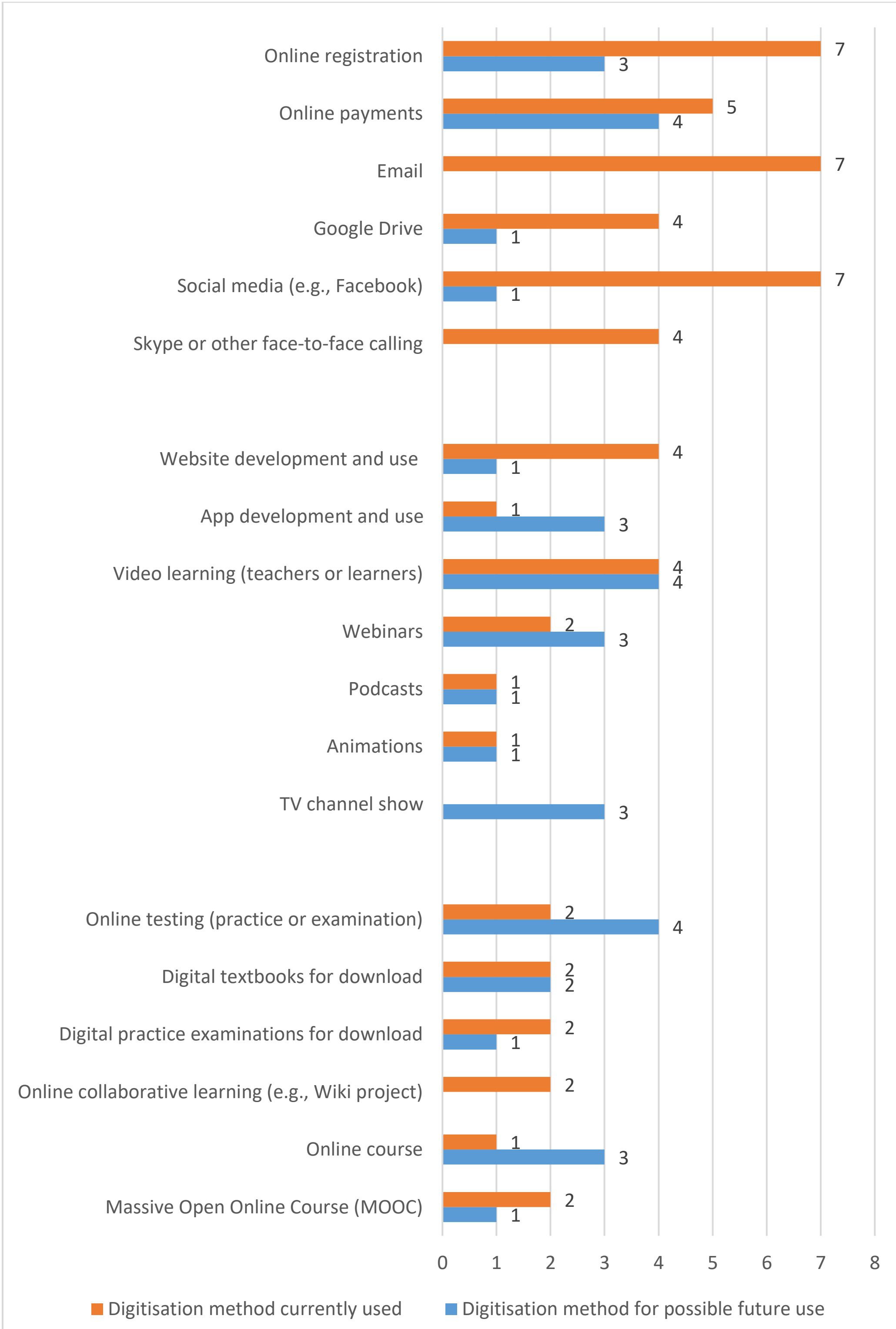


Figure 6: Digitisation methods used, or planned, to assist administration, learning content provision, and interactive learning (n=8)

The costs of using digitisation were largely related to development:

> *"Does not have costs for the end user, but the development of the database to capture and store information of the participating school, and also to avail resources like question papers free to the participants, is quite costly"* (O1B)

As this organisation noted, content creation is particularly costly after the initial setup:

> *"Most of our systems are self-developed, self-maintained and this means low costs to get started. Once created, the systems are automated, e.g. payments, online forms, etc. What takes time is content creation – this costs time and money"* (O7)

The above findings imply that it is easier to go digital for administration purposes than for content-driven programmes like Olympiads and competitions.

3.1.5 What digitisation methods may be used in the future by South African Olympiads and competitions?

As shown in Figure 6, some organisations related the use of digital methods to administration, including online registration and payments (O1B; O5; O8). However, organisation 5 noted as follows:

> *"… digital payments may be useful, but could never be used 100% because schools often do not have the finance infrastructure set up to deal with this (e.g. payment by credit card through an online payment portal)."*

In terms of providing learning content, several organisations noted application development for desktops and smartphones (O1A; O5), webinars (O1A; O8), YouTube training videos (O4; O6; O8), and online courses (O6). This could have several benefits. For example, webinars could be used *"to expand knowledge through interactive engagement of expertise outside of home bases"* (O8). For interactive learning, online practice papers and online question papers were noted (O1B) as well as digital textbooks (O8); the former indicates that organisations are interested in hosting Olympiads and competitions online, while the latter would *"reduce printing costs"* (O8).

3.1.6 What resources are required for digitation?

Figure 7 indicates the identified financial, human resources, and infrastructure requirements that are necessary for digitisation, with free or zero-rated connectivity being most often indicated by participants. When asked specifically about financial support, all respondents stated that this would be important to their success and was particularly related to human resources requirements. Organisation 7 commented: *"Absolutely! If I had a web developer, an app developer, a team of people to vet my content, money would go VERY far!"*. Several respondents further stated that they would use funding to appoint administrative staff, an application developer, and ICT personnel.

Some of the organisations have in-house expertise as well as volunteers, but these individuals have other full-time employment. Using funding to set up structure and train staff was also noted (O1B), as well as for purchasing digital equipment (O6). When asked specifically about human resources requirements, in addition to what is stated above, organisations stated that *"human resource would absolutely be very important element to train the rest of the staff members"* (O1B) as well as for *"managing and structuring the content of the digital environment"* (O2). Human resources with software development skills could thus be key in implementing digital Olympiads and competitions.

Specific responses regarding infrastructure requirements echoed what has been indicated in Figure 7: data centres and digital network infrastructure to schools; computers; laptops; and web hosting.

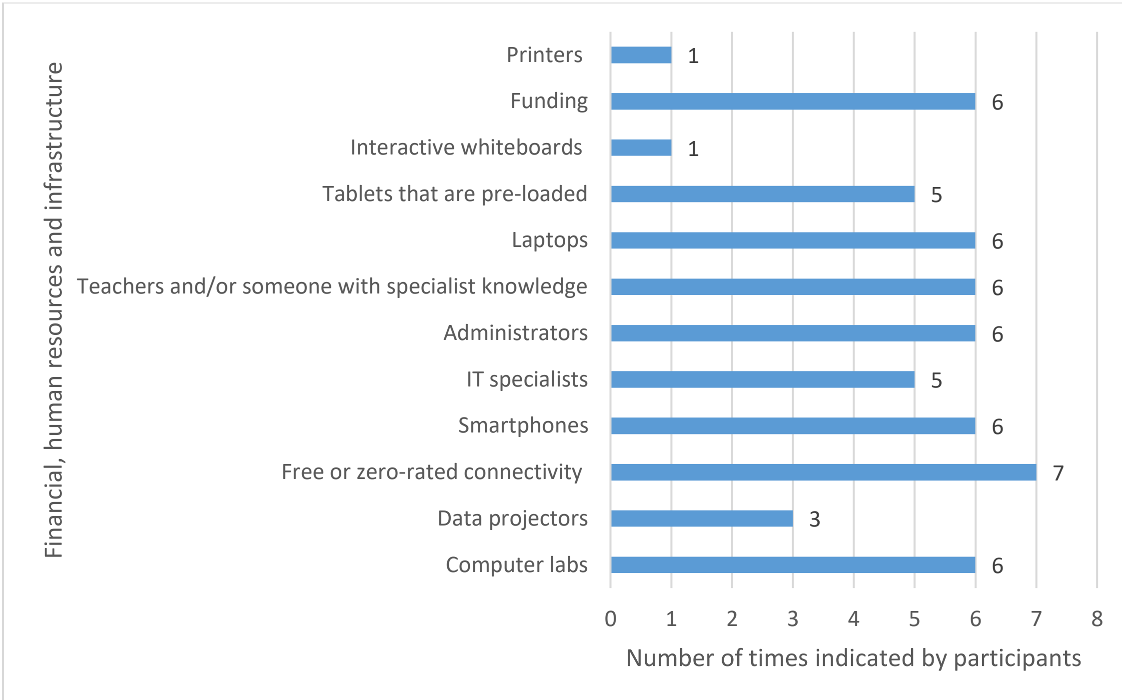


Figure 7: Identified financial, human resources, and infrastructure necessary for digitisation

The respondents were also asked if they would find an external consultant, an implementation policy, pilot studies, or a shared online platform of use in order to inform DSI so that they can assist the host organisations in the best way. With regard to an external consultant, there was strong division. Seven respondents stated that this would be helpful, mainly so that organisations would not have to waste time *"reinventing the bagel"* as one put it, and because *"a knowledgeable external person to lead the implementation of digitization will speed up the process"* (O8), particularly in *"the implementation of network and data infrastructure in remote areas"* (O1A). Two respondents did not find the idea of an external consultant useful. One organisation has had previous experience with external consultants and stated as follows:

> *"When we did hire external IT consultants in 2018, it was a DISASTER! External IT consultants have no concept of the educational landscape, and the requirements and limitations of schools, teachers, and learners. They cost us reputational and financial damage that year, and we would never do that ever again!"* (O5).

Given their experience, this organisation stated that they are willing to share their system with other organisations wishing to use a digital platform.

Providing an implementation policy, which is the standard operating procedures to develop online programmes, was deemed helpful as *“a generic implementation policy for all would be of benefit to be adapted to individual requirements”* (O4), but should not be restrictive (O7). Aspects to cover include *“scope of project, methodologies, applicable hard- and software, administrative and financial systems”* (O8). Opponents of an implementation policy noted that this would be too much paperwork and that *“it needs hands on experience from the administrators, working closely with the online platform IT developer”* (O5).

Pilot studies were noted as useful by all respondents. Primarily, it was noted that lessons could be derived from such studies, particularly for remote areas, and could be used to evaluate what works and what does not work. They are also regarded as important as organisations *“need to ‘train’ your schools/teachers/learners to use you online Olympiad, as well as identify gaps unique to your Olympiad”* (O5).

Finally, respondents were asked about the perceived utility of a shared online platform. Some organisations are already using a shared platform (O2; O4), while others met this possibility enthusiastically: *“Will provide a combined effort rather than multiple streams! DEFINITELY would support one STEM platform for SA! Tooooo many becomes overwhelming”* (O3). As stated earlier, organisation 5 is willing to share their platform, which manages the following aspects:

> *“Teacher, school and learner registration; payment management by generating invoices and receipts for schools; the upload of the Olympiad questions by the Olympiad organisers; hosting of the online Olympiad itself; the mass email of both administrative guidance to take part in the Olympiad, as well as marketing to schools/teachers/learners; the outputting of learners’ results for moderation and/or marking; report generation of the demographics of schools and learners; the generation and emailing of e-certificates to learners. Obviously some refinement IT development would be required for each particular Olympiad's needs”* (O5)

One organisation was against a shared platform, as there would be *“too much blaming when things don’t work out”* (O6).

When questioned about timeframes, responses were split between six months and two years, and this did not seem to be based on the size of the Olympiad or competition. For example, one organisation reached approximately 1 500 learners in 2016 and estimated six months for the implementation of digitisation. Another organisation, which reached approximately 700 learners in that same year, estimated two to five years for the implementation of digitisation. Both organisations relate to building robots (i.e. part of the competitions) and are operational in several countries including South Africa. However, the second includes Further Education and Training (FET) Phase learners (Grades 10–12) in addition to the other phases, whereas the first only includes the first three phases of schooling. It is likely that organisation-specific factors impact heavily on estimated timeframes.

3.1.7 Previous experiences in 'going digital' for South African Olympiads and competitions

Two organisations had conducted a pilot study to evaluate digitised Olympiads. In the first pilot study, hosted by organisation 1, five schools were identified to run the Olympiad on desktop computers. However, four of the schools did not had enough desktop computers and ultimately only one school was able to participate. In addition to hardware, schools also require additional invigilators for an online Olympiad, to ensure that learners can access the materials, provide assistance, and ensure that examination conditions are maintained. This organization held that an online Olympiad required more administration, volunteers, and time. In terms of benefits, *"one school could enter more learners than before"* and *"the costs of the Olympiad to the learners could be minimized"* (O1A).

The other pilot study was conducted in 2017 in both urban and more rural areas of South Africa by organisation 5 and was extremely successful. Their challenges related to user access control and a lack of resources in schools, as well as in setting up a digital website through which learners could take part. Despite the challenges, the respondent noted that this was *"much easier than couriering and marking 100* [multiple-choice] *scripts!"* and that there were *"lowered costs due to lack of printing, couriering, and marking"* (O5).

3.1.8 Anticipated outcomes should digitisation take place

3.1.8.1 Learner participation

Organisation 1B noted that *"learner participation will increase dramatically from schools in areas where they are able to access resources"*. These resources include both hardware and software, and connectivity, as well as guidance from educators or mentors. In addition, making activities available online *"will assist in preparation"* (O2) as well as having *"greater reach, more impact"* (O2). The sentiment of having a broader reach was echoed by other organisations, one of which stated the possibility of *"reaching larger numbers as no physical components are required but laptops/pcs and connectivity for software downloads and competition events"* (O4). Many respondents therefore anticipated that making activities available online would be beneficial in terms of widening access to Olympiads and competitions.

However, an organisation which required face-to-face participation had the following viewpoint: *"the quality of the learner should improve but not the amount of learners that will participate since the practical component cannot be done in the digital domain"* (O2). In referring to the quality of the learner, this indicates that having online learning materials available allows both educators and learners more opportunities for self-development. This can lead to a higher performance, or "*quality,*" by the learner.

Finally, organisation 8 noted that *"learners will be challenged in new ways which could cause distress."* This is a noteworthy concern, as distress can be detrimental to both learner performance and their self-perception or motivation. However, 'challenge' can also be a useful tool in the learning process and can lead to improved learner performance if used appropriately. The use of digitisation must therefore be managed so as to create a balance between challenge and frustration, improving learner performance and developing core technological skills.

3.1.8.2 Learner performance

Respondents stated that there will be both positive and negative impacts on learner performance. With regard to positive outcomes it was noted that learner ICT skills would certainly improve and that *"coding, strategizing, and problem solving solutions would benefit any learner holistically"* (O4). However, turning to possible negative outcomes, two organisations (O1B; O6) stated that it would take time for learners to become accustomed to an online mode but that performance would *"pickup as learners get acquainted with the digital platform"* (O6). These responses regarding both positive and negative results are echoed in the literature.

Previous studies have indicated that digitisation of education provides an efficient, effective, and productive method of teaching (Tunmibi, Aregbesola, Adejobi, & Ibrahim, 2015). It furthermore promotes learners' computer skills, critical thinking, and motivation to learn (Alwahoub, Azmi, & Jomaa, 2020; Tunmibi et al., 2015). It was also noted that digitisation provides access to an unlimited source of information and encourages a personalised learning path (Alwahoub et al., 2020; Tunmibi et al., 2015). The literature has also noted that the unfamiliar mode of learning can be overwhelming for learners, but, as stated above, this can be mitigated if the use of digitisation is managed correctly (Enyia, Ugbong, & Ewa, 2019).

3.1.8.3 Impact on the organisation

As a whole, digitisation was perceived to have many benefits for organisations. These centred on increases in organisation size and learner participation rates as well as improvements in the quality and efficiency of service delivery. With regards to administration, most respondents noted that future digitisation would be beneficial and that it would also enhance the efficiency of the competition (O1B; O3; O8). This includes collating online content and making it easily available, and easy to find based on needs, for educators and learners (O2). Looking at the possible impact on staff, respondent's listed increased workload (O2), necessary training (O1B; O3; O6), and the possibility of increased productivity (O8). They also noted that *"a more efficient system creates an easier environment"* (O4). Finally, respondents reflected on the costs of digitisation with agreement that:

> *"The cost of initial phases of digitisation will be massive, but will be manageable over time"* (O1B).

3.1.9 Anticipated outcomes should digitisation not take place

3.1.9.1 Learner participation

Respondents in general stated that digitisation will either have no impact on participation or would improve participation rates.

3.1.9.2 Learner performance

Respondents noted that not digitising would not have a large impact on learner performance. The benefit of digitisation would thus seemingly centre on increasing access rather than performance. However, the respondents did note that performance would be *"stagnant"* (O6) and that *"learners will be robbed on important IR4* [Fourth Industrial Revolution] *skills"* (O8) if digitisation were not to occur. The below quote, for example, notes that digitisation would enable learners to engage in subjects such as robotics:

> *"The robotics platform is one of the most demanding due to equipment costs and availability but there has been steady growth, and with the mandate of including coding and robotics into curriculum for more inclusivity a digital/virtual (less expensive) platform is imperative"* (O4).

3.1.9.3 Impact on the organisation

For the organisation as a whole, not digitising was seen as a sign of a lack of growth and that they might become *"irrelevant to schools who have already digitised their establishments"* (O1B). It was also noted that not digitising was a limiting factor, whereby organisations could not improve the level and amount of information that they could provide to educators and learners (O2), and would become inefficient and costly (O8). In terms of administration, some respondents stated that there would be no change, while others agreed that *"the administration is getting difficult, especially when numbers of those who participate increases"* (O1B).

For staff, not digitising was seen as limiting where *"the staff may in future have irrelevant skills and be unable to serve the needs of those who want to participate in the competitions"* (O1B). One organisation stated that the staff workload would remain the same (O2), while another believed that they would be administratively strained (O8). From the responses it was broadly perceived that not digitising would result in escalating costs, but specifics were not provided.

3.1.10 The role of stakeholders

3.1.10.1 Schools

Several roles for schools were identified, primarily to encourage participation and provide adequate ICT infrastructure as well as a venue in which to take part in the Olympiad or competition.

Training for schools in preparation for digitisation was deemed necessary but limited, such as providing *"online platforms to describe process"* (O1B) or *"email them a one-page guideline document as to how to participate in the online Olympiad"* (O5).

3.1.10.2 Educators

Roles for educators included: (1) project facilitator, (2) coach and/or mentor, (3) manager of learner registrations and payments, (4) invigilator, and (5) content contributor. Educators were thus noted as crucial to success, but also as *"overloaded with general education commitments"* (O4). It was recommended that educators receive recompense for their role, e.g. a stipend or airtime vouchers. For example, one organisation identified dedicated educators and pays them a stipend to act as centre managers. Training for educators was, in general, similar to that of schools depending on the organisation. Some organisations required educators to play a very active role and therefore to receive more intensive training. Using the same organisation from the previous example, they use trained engineering students to provide training and pay these students a stipend.

3.1.10.3 Learners

As the end user, most organisations stated that learners would need to have the ability to use electronics such as desktops, laptops, or smartphones (O1A; O1B). Learners would also need to be motivated as well as principled and not cheat on the online test. In terms of training, most organisations noted that this is necessary and would have to focus on how to use electronics.

3.1.10.4 Parents

The role of parents was based on support, with the possibility that they could also act as coaches and/or mentors. It was also suggested that parents could provide resources to learners if these were not otherwise available (O1B; O5).

3.1.10.5 Universities

Several important roles were seen for universities. Firstly, it was noted that they can provide resources: transport for learners; venues if exam conditions are required (for both test writing and presenting content); and training (both to local schools and to coaches and/or mentors on certain aspects). Universities can also *"create new knowledge in digital format and extend resources to* *schools"* (O8). It was stated that universities can *"engage with Olympiads to attract top performing students to their university/department"* (O5). Finally, universities can link organisations with volunteer students or unemployed graduates to assist with training and setup (O4).

3.1.10.6 Governmental departments

The role of the DSI was seen primarily as an enabler. This was largely related to funding and resourcing, such as sourcing and supplying electronic devices, supporting infrastructure, and providing platform licences in order to access the more robust systems. One organisation simply stated: *"Provide funding and do not hinder us with restrictive policies"* (O5). Another way to enable progress was to find how to incorporate unemployed graduates or tertiary students as part-time employed trainers; this could alleviate workload and add to an organisation's skillset (O4). Additionally, the DSI could *"incentivise learning hubs/clubs at libraries, schools or community centers with parent involvement"* (O2). Another role that was stated for the DSI was *"leading and rolling the project"* (O6), although this organisation also indicated this role for the DBE, and the Department of Higher Education and Training (DHET). Although DHET is now part of DSI, the survey instrument listed them as separate departments at the time it was administered.

Roles for the DBE echoed those listed for the DSI and supported their collaboration, indicating that there is great overlap. Respondents listed roles for the DBE that were related to funding and resourcing, such as sourcing and suppling electronic devices as well as educator training. In relation to the hubs/clubs noted above, it was indicated that the DBE can further support these initiatives. The DBE was also tasked by respondents with encouraging participation and marketing the Olympiads and competitions. Interestingly, the curriculum did not feature in responses from organisations.

Roles for the DHET related to encouraging universities to assist in the implementation of digital Olympiads and competitions, either through drafting regulations or through compulsory community engagement. Additional roles for the DHET included funding and resourcing as well as marketing the Olympiads and competitions.

3.1.10.7 Additional stakeholders

Respondents identified the following additional stakeholders: (1) private sector bodies who can provide funding; (2) relevant NGOs; (3) connectivity providers; (4) science centres; (5) education district heads; (6) SAASTA; (7) the National Research Foundation (NRF); (8) ASTEMI; (9) the South African public; and (10) international funders.

3.2 Insights from Olympiad case studies

3.2.1 Organisations interviewed[1]

The Computer Olympiad South Africa was initiated in 1984 by a group of educators who approached Old Mutual for funding. Participation in the Programming Olympiad in the first two years was under 100 learners, but in 1986 a two-round format was introduced which drastically increased entry numbers to over 1 000 learners. By 1990 this had increased to 2 000 learners and by 2003 to 3 000 learners (Computer Oympiad South Africa, 2017). The Talent Search was begun under the Computer Olympiad South Africa in 2003, as an aptitude test. It was instigated as a reaction to many learners waiting until Grade 11 or Grade 12 to take part in the Olympiads, which is too late to influence their choice of subjects, which happens at the end of Grade 9. This additional Olympiad further increased participation, as it alone had more than 11 000 entries in 2003, 13 000 in 2004, and 15 000 in 2005. The Talent Search currently has over 35 000 entries from schools across the country, and is provided in *both an online and a pen-and-paper format* (Computer Oympiad South Africa, 2017). The Applications Olympiad was initiated under the Computer Olympiad South Africa in 2010 to enable participation from learners who take Computer Applications Technology (CAT) or Computer Literacy as school subjects. The Computer Olympiad has several aims, including to identify, encourage and reward computer aptitude; promote and encourage computer studies; and create an awareness of career opportunities in ICT (Computer Oympiad South Africa, 2017).

The annual online Geography Olympiad in South Africa (SANGO) was launched in 2017 under the guidance of the Southern African Geography Teachers Association (SAGTA) and the

[1] Supplementary material includes detailed case studies of each organisation interviewed and can be obtained from Ms Ncamisile Zulu (nzulu@hsrc.ac.za).

Society of South African Geographers (SSAG). SANGO aims to foster a love of geography at high school level, and in so doing a feeder system for tertiary studies relating to geography and to send a South African team to the International Geography Olympiad (iGeo). On the day of the Geography Olympiad schools must ensure examination conditions and adequate Internet facilities for learners to access it, avoiding venue costs. Schools then provide learners with an online link to the Olympiad (which the organisation will have sent earlier that day). Only learners with pre-registered and successfully activated profiles are able to participate on the day.

The South African Physics Olympiad (SAPhO) aims to identify FET phase learners with ability in Physics, raise the awareness of Physics, show how Physics impacts our daily lives, and encourage learners to study physics. Learners who achieve well in other National Science Olympiads are invited to participate in SAPhO and entry is free. The test comprises 50 multiple-choice items which go beyond the curriculum, and learners have 90 minutes to complete it (ASTEMI, 2020). This short time period ensures that no cheating takes place. In addition, a unique marking system is used to prevent guessing: 4 marks for correct; 0 marks for incorrect; 1 mark for 'not knowing' (or not attempting the item).

On the day of the test the items are emailed to the schools, which print them and return the completed answer sheets once the test has been written by the learners. Importantly, the organisers of SAPhO have noted that although the test can be completed online (a digital, online mode), the majority of learners prefer the pen-and-paper version as it is easier for them to scan the items and flip back and forth. Other negative aspects of using an online version include: (1) difficulty in doing diagrams, (2) lack of access for some schools, most likely rural and poorly resourced schools, and (3) preparation for the test is more difficult and time-consuming for the organisers. However, the online version does have benefits: (1) marking is easier, fairer, and allows for nuances, and (2) data processing and analysis is quicker and more accurate.

With regard to mass participation in Olympiads and competitions, it was recommended that digitisation must start in schools, so that learners become familiar with technology and with taking tests using technology.

3.2.2 Lessons learnt from digital Olympiads

The Computer Olympiad South Africa incorporates both computer-based and pen-and-paper platforms and is thus suitable for the South African context. Conducting Olympiads using this blended approach is beneficial, as it does not restrict learners' access to the event if they do not have connectivity. This approach also allows for gradual progression to the use of technology for schools, educators, and learners who do not have the required resources or who are not computer literate. This host organisation also emphasised the importance of collaboration to assist in funding, sponsorships, personnel and equipment in digitising Olympiads. Partnerships with particularly universities and sponsorship companies were highlighted.

The SANGO uses an adaptive website as their platform, which means that it can be accessed via desktop, laptop, smartphone or tablet. This adaptive website means that there is no need for paperwork, marking, or couriers, and that it is nationally accessible. This is especially useful for the host organisations and educators, who normally deal with the administrative tasks. This organisation highlighted the importance of involving a capable professional developer in the development of the website platform, as a poor developer can have detrimental effects on the website and participation in the Olympiads.

The SAPhO showed that while digitisation is very possible – indeed a software application has been developed which can be completed online – learners preferred to use pen and paper because that is how they are accustomed to writing a test. It will be prudent to ensure familiarity before a transition can be made to digital.

3.3 Insights from competition case studies

3.3.1 Organisations interviewed[2]

The Eskom Expo for Young Scientists is an exposition, or science fair, where students have a chance to showcase their projects about their own scientific investigations to their peers. These scientific investigations are in four main streams: scientific investigations; engineering type and computer science; mathematics and theoretical projects; and social sciences. Participation takes place face to face and there are several stages involved. It is important to note that *implementation included the efforts of over 3500 volunteers*. Roles for volunteers range from acting as mentors, to setting up the venue and judging presentations.

[2] Supplementary material includes detailed case studies of each organisation interviewed and can be obtained from Ms Ncamisile Zulu (nzulu@hsrc.ac.za).

The first stage takes place within the classroom, as it is a Curriculum and Assessment Policy Statement (CAPS) requirement that students undertake a project (DBE, 2011). It is therefore very important that the educator is able to facilitate the preparation of these projects should learners wish to compete. It is noted that schools within rural and township areas, the quintile 1, 2, and 3 schools, are disadvantaged in pursuing the competition further than the classroom. There are thus mechanisms in place to assist, which includes volunteers entering those areas to promote participation. The second stage is at the school level while the third is at the District level. From there, the best learners go on to the fourth stage, which is to compete at one of the 35 Expo Regions within the country. In 2019 this involved approximately 17 000 projects. The fifth stage is at the country level, where the top students in the country compete against one another. In 2019 the competition had 500 projects at this level. Finally, the top 20–25 projects go on to compete in international science fairs, such as those held in Taiwan and Malaysia.

The main aim of the Govan Mbeki Mathematics Development Centre (GMMDC) is to develop content knowledge and skills in Mathematics and Physical Sciences among learners and educators at FET level. The organisation has subsequently, extended its focus to include the Senior Phase for secondary schools. Such initiatives have led to the unique customised offline techno-blended model (TBM) for teaching and learning in under-resourced schools, and linked development programmes for learners and educators. These have seen real results in the classroom, most importantly, the boosting of learners' marks.

A common thread through all programmes has been a focus on harnessing technology to reach the new 'screen generation' of learners, who cannot imagine a world without TVs, mobile phones and computers. The programmes give learners a chance to improve their CAPS Mathematics and Physical Sciences marks, thus improving their chances of gaining access to and being successful at university. An example of their programmes is the TouchTutor® Quiz application (now known as the MobiTutorZA application and available as a smartphone download), which is both online and offline. This means that the user must be online to register and they can take the topic-based tests online. However, they can also download each test and complete it offline, and their results will be uploaded when they are next online. In this way, learners in deep rural contexts can go to a WiFi access space, download (on the smartphone) the test and learning resources they need for the next month, leave and continue to use the application for free. Creation of these tests is labour-intensive and therefore require partnerships. PDF downloads, past papers, memorandums, and videos are all included on the application. The TouchTutor® Quiz application therefore supports teaching and learning without a need for extensive Internet access.

The Virtual Get Excited About Robotics (GEAR) competition is hosted by the Inspired towards Science Engineering and Technology (I-SET) community engagement flagship project of the College of Science, Engineering and Technology at the University of South Africa. The aims of Virtual GEAR are to inspire awareness and interest in STEM subjects, provide practical experience in robotics to develop various skills, and develop a community of learning. This competition takes place internationally (Germany, United States, Costa Rica, and South Africa), but the robots are designed and tested locally under the guidance of a coach. Registration is through Google Drive, with further interactions and the actual competition taking place through video uploads to WhatsApp and Google Drive. Support and engagement are also provided by previous competitors and through social media, e.g. online tutorials, YouTube videos of robotics competitions, virtual communities of learning, Facebook groups and posts, as well as research papers (Gouws, Karp, & Pheeha, 2017).

3.3.2 Lessons learnt

The Eskom Expo for Young Scientists reminds us of the value of conducting some interactive competitions face to face, as this enables an important space for mentorship and development of a wide variety of skills, and enables learners to learn from their peers and experts. The usefulness of incorporating digitisation in the administration processes, broadcasting of training sessions for educators, as well as making resources and guides available online was emphasised by this Expo.

GMMDC developed their application with the South African context in mind, as it offers both the online and offline system. This means that those learners who do have access to a device but do not have much data can also be included in these digital competitions. Their application also includes a multilingual mathematics glossary. This is particularly useful for the South African context, where learners are taught in a language that is not their mother tongue. Users can access explanations of mathematics concepts that are presented on demand, with English side-by-side with any other chosen indigenous language. The advantage of the application is that once downloaded, the participant can have readily available access to the practice questions and answers and other resources for learning. They do not have to wait for a hard copy practice paper. GMMDC also engages with educators to recruit learners to participate in the digital competitions.

Virtual GEAR provided further examples of using digital methods for the administration and implementation of the competition. In addition, it highlights the key role played by peer learning, mentorship, and a community of learning.

3.4 Insights from ICT experts

The three ICT experts recommended a hybrid (comprising both a paper-and-pencil and digital, either online or offline) approach to implementing digital Olympiads and competitions in South Africa, as this is *"popular and necessary* [for fairness]*"*. They also noted that there is no single approach which can be taken to implement a digital science Olympiad or competition within South Africa; the approach depends on infrastructure and the features of the activity itself. Nevertheless, this section presents three general steps identified by the interviewees in order to develop a digital platform (e.g. application or website), referred to as the system development life cycle.

Following discussion of this general process, key challenges and points to consider in relation to our context and utilising a hybrid approach are given. In addition, the interviewees provided approximations of both timeframe and costs for implementing digital Olympiads and competitions in South Africa.

3.4.1 Software development life cycle

3.4.1.1 Phase 1: Consultation and planning (40% of timeframe)

Understanding the target market is the first step, and involves a clear understanding of the end users: the profile of the learners. Different categories can be used to build these profiles, such as location, income, access to devices, age, gender, etc. After a survey, (six) focus groups can be held with each category in order to gain further understanding of the different categories, their involvement in the science Olympiad or competition, and how they might use a digital method. Learners' previous experiences of participating in Olympiads and competitions will be different, and thus focus groups will provide rich knowledge of how they are used to participating, which can be incorporated into the design of the platform. They will also provide insight into possible issues that end users might encounter in using a digital platform.

It is important to get a nuanced understanding of the different types of end users, as this will help in getting a detailed picture of who is participating, what (technological) resources they do or do not have access to, and at what capacity. This understanding informs the decision as to whether an online-, offline- or paper-based platform is pursued for the particular science Olympiad or competition. In some instances, all three of the abovementioned can be developed. For digital platforms, this stage will also determine what types of platform could be used, e.g. smartphones, desktop computers, laptops, etc. The interviewees recommended a hybrid approach where both digital and pen-and-paper tests are used.

The type of information to be captured must also be decided, which is linked to the type of platform. For example, if it is a digital, online application then the technology must capture the information which must be incorporated into the design. However, if it is a digital application which can be completed offline and later uploaded, it must be determined who will upload this information and how, which is incorporated into the design. Finally, a paper-based test must be manually captured and the individual who will do so must be identified, which will also guide the design.

3.4.1.2 Phase 2: Design, development, and testing (20%, 20%, and 10% of timeframe)

The design and build is typically led by an ICT-based service provider and takes place with the identified target market in mind. This involves development of the questions and decisions regarding the type of content to be captured. It also identifies who will be answering the items and who can verify that the information or items were captured correctly and in a trustworthy manner. If paper-based methods are also to be used, which do not have automatic marking, data capturers that will take the information and capture it on the system also need to be taken into consideration during the design process.

During the software design and development phase the host organisation guides the ICT-based service provider on the ‘business rules’ which need to be built into the software. Business rules are used to tell the software what to do if a specific, predetermined event takes place. For example, if the learner indicates that they are comfortable with the English language, then the business rule would tell the software to present the question in that language. Likewise, if the learner indicates that they are comfortable with isiZulu, then this language should be used. In this way various learners may participate, but have selected questions tailored for them. Possible options within the Olympiad or competition are regional questions, age-/grade-specific questions and language options. Most ICT-based service providers within the South African context do have an understanding of our environment in schools; however, the process of clarifying the business rules is necessary.

An iterative and consultative approach, i.e. multistage testing, should be undertaken. Three versions should be used:

- the first contains the first round of features and digitised content, to run a test Olympiad with target groups;
- feedback from these groups is then incorporated into a second group, which is also tested; and
- finally, a third version is built and tested.

End user testing is thus a crucial component of software development and takes place over several (10–12) months, with focus groups in diverse areas of the country to provide reasonable generality. It is important to test with actual users. The focus groups are provided with the platform to perform the activities in order to evaluate its functionality and usability and other features. This testing also includes researchers and other collaborators of the host organisation of the science Olympiad or competition, fieldworkers, and the ICT-based service provider.

Testing functionality evaluates whether the business rules are being translated accordingly. Usability of the platform must also be tested, because some can be functional but not usable. The security of the platform and accessibility to those who will be accessing it online are also tested. Finally, the strength of how the application performs when it is accessed by 100 participants, 1 000 participants, 100 000 participants, or more is tested. This informs the limit of how many users the digital platform can handle at a time before it becomes slow or, worse, crashes. It furthermore provides an indication to the host organisation of the necessary infrastructure to cater for their number of users. The infrastructure must be able to handle the requests, otherwise the digital platform becomes very slow and users might even end up completing the science Olympiad or competition very late because of this.

3.4.1.3 Phase 3: Implementation (10% of timeframe)

At the end of the design, development, and testing phase, a production-ready platform for the real science Olympiad or competition is available. This final phase is thus the roll-out. Here the ICT-based service provider is necessary for maintenance, updating, training for the intermediaries (those putting the content on the system), and addressing bugs or other issues which only arise in the field. For this phase to take place in a digital manner, various requirements must be in place, and devices and connectivity are essential. These requirements are discussed in the final key findings section.

3.4.2 Challenges in utilising a hybrid approach in the South African context

The following challenges to using a hybrid approach were identified by the ICT experts and are presented here in terms of affecting host organisations, learners, or both. The challenges largely relate to using a digital method. To prevent duplication, effective means of combatting these challenges are presented in the final key findings section.

3.4.2.1 Host organisations and end users

Connectivity and available devices will be a challenge for the majority of learners, particularly those in rural areas. ICT experts estimated that only a small percentage of learners in rural areas would have digital means. In addition, the situation in the different provinces varies hugely. For example, Gauteng has an online program with massive tablet roll-out costing approximately R4 billion. Limpopo, on the other hand, would be at the opposite end of the spectrum. One ICT expert noted that it is not merely access to connectivity and devices, but also the quality thereof which has implications for fairness. For example, *"the highest connectivity availability is mobile, but there are major differences in devices."* With regard to using the system, both host organisations and end users will need training in and sensitising towards the system. This will assist with managing the risk of challenges arising during the actual science Olympiad or competition.

3.4.2.2 Host organisations

The host organisation, together with the ICT-based service providers, will need to ensure adequate protection of data and personal information entered into the digital platform. In addition, they will need to monitor that this information is inputted by the correct individual. With regard to content, if the host organisation goes beyond more than a PDF or MS Word document and includes graphics or interactivity, there might be some content creation and management risks. There are also implications regarding the device which can be used: science has complex concepts, and completing the activities may have to take place via desktop computer or laptop, and possibly tablet.

3.4.2.3 End users

Availability of electricity and charging of devices may be challenges for the end users. Educators may also be unfamiliar with technology and differ in their receptiveness to it.

3.4.3 Estimated timeframes for South African Olympiads and competitions to go partially and/or fully digital

ICT experts noted that timeframes are highly dependent on the content which is being digitised. They provided examples in order to express this:

- Single test or examination – 6 months;
- Infrastructure and digital platform – 18 months to 5 years.

This second estimate varies widely, as it involves taking into account governmental processes and consultation as well as on-the-ground consultation with focus groups, design, and testing. Another factor here is whether the host organisation wants to ensure that participating schools have full network coverage and that there are devices for each learner which are always available. In the latter instance, this will take five years as other ministries and/or departments may also be involved. However, if this is not the aim and the host organisation wants to run their activity on an existing platform, such as SurveyMonkey, then it is possible for it to be implemented and rolled out in several months. The reader is referred to the 40:20:20:10:10 ratio outlined for the system development life cycle. The planning stage received a high percentage of the timeline as it is a crucial step: if this is not done efficiently then the initiative can fail, and stakeholders would then have to go back and begin the process again.

3.4.4 Estimated costs for South African Olympiads and competitions to go partially and/or fully digital

Cost implications are dependent on factors such as the number of learners that the host organisation caters for and other complexities, leading to a wide variety of estimations. Again, several examples were given:

- Multiple-choice test on SurveyMonkey with option to download a PDF, complete on paper, and later upload responses: R5 000 – R10 000
- Questionnaire on cloud-based platform such as SurveyMonkey or Google Forms: R50 000
- Infrastructure and a well-developed application where individuals create user accounts, answer questions, view their history, view previous science Olympiads or competitions, and where the host organisation has their own custom platform on which to upload content which is interactive (goes beyond PDF or MS Word), and caters for a million users: R10–20 million or more

3.5 Insights from international studies

3.5.1 Internationally held Olympiads

Many insights were gained from reviewing two Olympiads which are held internationally with regard to how digitisation can be implemented effectively. The first illustrates how digitisation is able to ease the administrative burden of hosting a large national Olympiad for thousands of learners. In the second, we see how pen-and-paper options complement digital programming in order to increase participation and prevent exclusion.

Aroca, Pazelli, Tonidandel, Filho, Simes, Colombini, Burlamaqui and Goncalves (2016) discuss the Brazilian Robotics Olympiad (OBR). The objective of the OBR is to increase interest in robotics and technology among elementary and high school learners. The authors noted how a web-based automated system, developed to manage the OBR, enabled only a small organising team (two paid employees assisted by volunteers) to cater for 100 000 participating learners. It is named the “Olimpo System”. In the planning stages of the event, 1 500 educators and professors are invited to propose questions through a module of this system. The system furthermore allows: (1) educators and learners to register; (2) regional and local coordinators to control their activities; (3) educators to upload the results of their learners; and (4) certificates to be automatically assigned and sent to participants (Aroca et al., 2016). As learners are registered in the system it allows them to be tracked. An additional milestone which allowed for growth of the OBR is the availability of documents, first created during the 2012 event and continuously updated. These manuals are available on the OBR homepage and include: (1) a study guide/manual for the theoretical exam;

(2) question elaboration guidelines for the theoretical exam; (3) rules and a manual for the practical exam; (4) a regional event preparation manual; and (5) a referees' manual (Aroca et al., 2016).

Burton (2008) discusses the activities in Australia that support and complement participation in the International Olympiad in Informatics (IOI). Activities include programming competitions, pen-and-paper competitions, and others. For example, they host the Australian Informatics Olympiad (AIO) as an entry-level programming contest. However, it was noted that the AIO had extremely low participation, which was likely due to: (1) the difficulty of running programming contests, as opposed to pen-and-paper tests, which require enough computers, appropriate software, and a technologically competent supervisor, and (2) the need for learners to have enough programming knowledge to create a running program for grading. The programming contests are thus complemented with a pen-and-paper contest: the Australian Informatics Contest (AIC). Both the AIO and AIC are thus informatics competitions, but the AIC is mostly presented as puzzles where learners use informal algorithms in their head to solve them (Burton, 2008).

3.5.2 Development and use of software

As noted in the introduction to this report, creating interest in STEM fields is one of the DSI's aims. Bryce, Mayo, Andrews, Bokser, Burton, Day, Gonzalez and Noble (2013) review their Bug Catcher, a web-based system for running software testing competitions, and the impact that participation in such a competition has on interest in Computer Science. In their study, the authors hosted a Software Testing Competition over a two-day period at a school camp for 94 high school learners without previous programming experience. On average, teams found 53-77% of the possible bugs, and post-survey results showed that 73% of learners had an increased interest in Computer Science (Bryce et al., 2013).

Computer Science Circles is a free programming website which teaches Python in an easy to understand manner which is designed for beginners (Pritchard & Vasiga, 2013). The website comprises lessons with embedded exercises to facilitate learning. Although the exercises are automatically graded, learners can send a 'help' message when stuck. This feature was added to provide a human touch rather than relying on automatic grading alone. Although this feature sends the message to the authors by default, educators (or mentors or tutors) who wish to use Computer Science Circles can have their learner's queries redirected to them instead. Educators can also track the progress of their learners (Pritchard & Vasiga, 2013).

3.5.3 Role of universities and students

International literature allowed for the identification of a niche for universities and their students in assisting in the implementation of Olympiads and competitions. Dodds and Karp (2006) discuss how a small college in the United States initiated a computational outreach program to under-represented groups in Computer Science at a local high school. Although this program focused on undergraduate students, providing enrichment activities to learners (Dodds & Karp, 2006), there is an important take-away for science Olympiad and competition organisers: some activities which require tutors or mentors may be able to be facilitated by undergraduate students. Another role was identified by Christensen, Rundus, Perera and Zulli (2006), who organised a voluntary group of Computer Science and Engineering students, termed the CSE volunteers, to provide IT support to a school district. The expected time commitment for students was four hours per week, for an academic semester of 15 weeks. Volunteering in this program was beneficial for students, as they were able to gain real-world experience in managing large-scale IT operations, thus participating in in-service learning. Typical work included setting up new computers, dealing with viruses and other security issues, and the installation of new software (Christensen et al., 2006). With regard to Olympiads and competitions, there are a myriad of ways in which such a programme would assist, e.g. setting up for test day, providing ICT maintenance, etc. The Virtual GEAR robotics competition presented as a case study in this report is a current example of such a community.

3.5.4 Comparability of scores

Since the advent of computer-based assessment, instead of to pen-and-paper assessment, concerns have been raised regarding the comparability of score meaning. Comparability in this context refers to the “commonality of score meaning across testing conditions including delivery modes, computer platforms, and scoring presentation” (Bennett, 2003, p. 2). Variation in these conditions may lead to low comparability. Furthermore, such variation has the potential to impact certain groups unfairly. For example, school socio-economic status may be related to computer platform quality or computer familiarity, which would then impact score comparability (Bennett, 2003). In a later study, computer familiarity was shown to have a significant impact on Mathematics performance, where higher familiarity was correlated with higher achievement (Bennett, Braswell, Oranje, Sandene, Kaplan, & Yan, 2008). Certain steps can be taken to limit variation, namely:

- Delivery mode: Equation of scores; or separate scales for computer-based and pen-and-paper versions.
- Computer platforms: Establishing hardware and software standards; directly manipulating font characteristics and resolution through test delivery software; designing items for adequate display at the lowest possible resolution; or presenting items in such a way as to limit scrolling.
- Scoring presentation: Rater training to avoid bias concomitant with response format (i.e. typed or handwritten essays) (Bennett, 2003; Bennett et al., 2008).

Other factors which may impact learner performance on a computer-based test include technology problems during test administration, e.g. interruptions due to loss of Internet connection or a hardware or software issue. Such problems can negatively impact concentration and motivation (Bennett et al., 2008). Bearing in mind that computer-based testing is still being introduced into the South African context, it is recommended that studies be performed to explore comparability and the effectiveness of computer literacy tutorials. This can be incorporated into pilot studies of digitised Olympiads and competitions.

4 Key findings and discussion

4.1 Readiness for digitisation

4.1.1 Host organisations

Across all forms of data collection, i.e. survey and interviews, it was noted that the host organisations were positive towards digitisation, but that they had reservations regarding to what extent it could be achieved or used. This was for various reasons, but primarily: (1) some host organisations require and/or prefer face-to-face interaction for their activity, and (2) purely digitised activities may not reach all South African learners. For these reasons, participants preferred a hybrid mode comprising both pen-and-paper and digital (either online or offline) Olympiads and competitions. This allows host organisations to choose a solution which is best suited to their activities.

In terms of readiness to offer digital activities, again there was variation across host organisations. Some used purely pen-and-paper-based activities without any digitisation, and some were pen-and-paper based but used several digital methods, such as online registration through a website, whereas others were already fully online. Using available technologies for the administration and management of the science Olympiad or competition is key to efficiency and communication, it seems. This includes conducting entries and registrations on a digital platform such as email, or via a website, WhatsApp, etc. Another option is using email to send the science Olympiad questions or competition activity. The school or educator can then access the email, print out the Olympiad questions or competition's activity, hand it to learners, and the learners can then write the Olympiad or start with the competition activity, such as building a model or researching for a poster presentation. Training manuals and past papers can also be emailed to participating schools and learners in a PDF or video format, or the schools themselves can download them via the host organisation's website.

Using such technologies to enable learners to access supportive and practice materials and engage with each other allows learners the opportunity to: (1) increase their learning opportunities, (2) practice their skills, and (3) develop a community of learning. The organisations can also use digital platforms such as social media to market their Olympiads and competitions. Certificates of participation can also be emailed to learners rather than couriered, saving costs.

4.1.2 End users

Due to the digital divide within the South African context, only a minority of schools, educators, and learners could be said to be ready for digitisation. This goes beyond access to devices and connectivity, and includes familiarity with technology. Educators may be opposed to the science Olympiad or competition if they are unfamiliar with the technology being used. For learners, a lack of familiarity may negatively impact their achievement in digital Olympiads and competitions. It will therefore be necessary to provide training to both educators and learners.

4.2 Requirements for digitisation

4.2.1 Host organisations

All information needs to be consolidated and stored in one place, termed a data centre, by the ICT expert. A data centre is considered a necessary component of the infrastructure in order to host a digital science Olympiad or competition, and includes aspects such as servers and storage systems. A data centre capable of handling requests from potentially millions of learners at a time can cost R5–6 million. A host organisation can have their own data centre, but it is also possible to share a single data centre or use existing infrastructure (e.g. MTN, Vodacom, or another cloud-based repository) and pay for this use. This infrastructure provides: (1) capacity for hosting the information of potentially millions of learners, (2) easy access to information despite size, (3) no need for host organisations to maintain this data centre, and (4) lower costs than setting up own data centre. Host organisations would need connectivity to access the information in the data centre.

Another important consideration for the host organisation is to assess whether learners have access to the necessary devices and to connectivity, as this impacts the organisation’s processes and use of digitisation. If learners do not have devices or connectivity, it is possible to have an application pre-loaded on devices, which are then taken to a central location where learners can complete the activity. This is a digital, offline method. These devices would then be returned with the learners’ data on them. These data can be uploaded once the devices have access to connectivity. This, in turn, requires fieldworkers as well as accessibility to the school or central location, which may be difficult if it is remote.

It is also possible to use a digital, online method in areas with limited connectivity in partnership with mobile network providers. These areas have poor coverage, but mobile network providers have built infrastructure to provide basic services, which can then be used to provide connectivity for the digital science Olympiad or competition. This can be supplemented with zero-rated connectivity, data subsidies, data vouchers, or provision of actual data. Other required resources and infrastructure include laptops, smartphones, and tablets that are pre-loaded.

If a digital platform is to be developed, as illustrated by the software development life cycle, there are several steps: (1) consultation and planning, (2) design, development, and testing, and (3) implementation. Many respondents welcomed a shared platform. One organisation offered the use of their platform which includes the following:

> *"Teacher, school and learner registration; payment management by generating invoices and receipts for schools; the upload of the Olympiad questions by the Olympiad organisers; hosting of the online Olympiad itself; the mass email of both administrative guidance to take part in the Olympiad, as well as marketing to schools/teachers/learners; the outputting of learners' results for moderation and/or marking; report generation of the demographics of schools and learners; the generation and emailing of e-certificates to learners. Obviously some refinement IT development would be required for each particular Olympiad's needs"* (O5)

There are also different types of cloud-based software applications which are available either free of charge or at a fee. This includes Google Forms, SurveyGizmo, Type Form, QuestionPro, Zoho Survey, KwikSurveys, Moodle, and others. Some of these applications are customisable, with advanced features allowing the insertion of graphics. This is important for science-related items. More basic applications cannot be customised in this way and are better suited to simple formats such as multiple-choice questions. For content creation and management, a recommendation is to introduce the digital activity via a PDF or MS Word document, or other low-tech means, and then gradually move to a more interactive graphic.

For completion of digital activities there must also be proper controls in place to address the issue of validating that the activity was done by the correct person, and that there was no cheating. This includes recording the location, measuring how long it took for the user to complete each item, and having a set date and time in which to perform the activity.

In terms of personnel, for a digital activity an ICT professional or developer as well as a data manager would be required. The former can assist in training the host organisation and end users as well as maintenance. The latter individual would validate whether the received data are correct according to what was expected. They would also be able to package the data for use. Survey and interview responses also identified administrators, educators or a person with specialist knowledge, an internal media officer and a bookkeeper (if there is a fee to take part) as key personnel. Beyond employed personnel, volunteers are a crucial aspect of running a digital science Olympiad or competition and may perform roles such as administrators, mentors, coaches, invigilators, and content contributors. Here universities can play a crucial role. For example, lecturers can provide content for the event, while undergraduate or graduate students can act as tutors or mentors or provide ICT support (see Moodley, 2018).

An implementation policy was regarded as useful by the majority of survey respondents and should include: (1) scope of project, (2) methodologies, (3) applicable hard- and software, and (4) administrative and financial systems. Pilot studies were also considered useful. In terms of the software development life cycle, it may be prudent to use a pilot study for the final launch of the completed software. This will provide valuable feedback for later roll-out on a more national level. A pilot study will also allow educators time to become more accustomed to and familiar with technology, and give the host organisation the opportunity to provide more assistance with a smaller sample. Pilot studies will also be useful to evaluate the comparability of scores between learners who took the test digitally and those who completed a pen-and-paper test.

Survey respondents and host organisations all stated that funding is essential to their success with digitisation. Adequate time is also essential, and ranged between six months and five years, depending on the scale of the project.

At the macro-level, the role for governmental departments was primarily as enablers of the digitisation process. This was largely related to funding and resourcing, such as sourcing and supplying electronic devices, supporting infrastructure, and providing platform licences to access the more robust systems. Beyond collaboration and interdepartmental support, unique roles for each governmental department which were stated were:

- DSI: Incentivise learning at public hubs
- DBE: Educator training; encouraging participation and marketing of the Olympiads and competitions

- DSI-DHET section: Incentivise universities and students to assist in the Olympiads and competitions.

4.2.2 End users

While devices and connectivity are a concern for the end users, this will most likely be addressed by the host organisations.

4.3 Potential impact of digitisation

4.3.1 Host organisations

It is anticipated that digitisation will have a largely positive impact on host organisations, as it contributes to efficiency and lowered costs. It will also assist them to provide more materials to schools, educators, and learners, and to attain a higher learner participation rate. However, this will need to take place through a hybrid model, as not all end users within South Africa have adequate access to technology to afford them the necessary opportunities. Respondents also foresaw an increase in staff workload and a need for staff training, but also the possibility of increased staff productivity.

4.3.2 End users

Survey respondents indicated that digitisation will dramatically increase learner participation in areas where they are able to access the resources. It will also assist in preparing learners, as they will have more opportunities to practice and engage with a community of learning, improving their performance. In addition, the ICT skills of the learners would be improved, which is important for their future entry into the workplace.

For Olympiads and competitions which require face-to-face engagement, there are still benefits, but not in terms of increased participation. Here the benefit lies in the learner's increased ability to practice their skills on a digital platform before the actual event. It is thus largely agreed that digitisation will have positive impacts on both learner participation and performance or achievement.

However, it was also put forward by respondents that digitisation brings new challenges to learners, which may cause them anxieties. The hybrid model is thus also of use here, as those learners for whom digitisation would have a negative effect on participation and performance can take part via pen and paper instead. Furthermore, the technology can be introduced gradually in order to allow learners time to become acquainted with and transition to a digital mode.

5 Conclusion and summary

This report has integrated learnings from various sources to establish the state of readiness for implementation of digital science Olympiads and competitions in South Africa. It is concluded that digitisation is cautiously supported, both due to its benefits and for progression, the latter referring to keeping up with global technological innovations, and that it is currently being used to varying extents.

Regarding its use, digitisation has been found to be particularly useful in the administration processes of organisations, learning content provision, and interactive learning. It is anticipated that the increased use of digitisation in hosting Olympiads and competitions will improve learner participation rates, hosting organisation size, as well as the quality and efficiency of service delivery. Therefore, in moving forward, digitisation of both the (i) administration processes, and (ii) Olympiads' and competitions' activities need to be carefully planned, implemented, and managed to best suit the needs of the host organisation, educators, and learners. Each solution will depend on the organisation itself, its offered activity, and the learners it aims to reach.

There will therefore be varying degrees of digitisation. For example, some organisations may want to host their Olympiad or competition entirely online for mass participation, whereas others may want to use digitisation in their administration processes and offer certain materials online, but retain a face-to-face event. Therefore, in this final section we summarise certain essential requirements for digitisation as well as identified best practices, as well as noting when pen-and-paper or face-to-face methods may be preferable.

For digitisation in general, **the relevant technological infrastructure, hardware, and software** are necessary and may include:

- Data centre which can be shared by host organisations, or they can use an existing infrastructure, such as a network or cloud-based repository.
- Devices and access to connectivity, e.g. schools' or learners' devices or pre-loaded devices provided for the event.
- Personnel, including an ICT professional or developer, data manager, and administrator.

In making this available, there must be **alignment** across DSI-DHET and DBE government departments to create a **strategy policy for the transition** of Olympiads and competitions from pen and paper to digital, development of a data centre, and development of a shared platform. This will create a coherent framework within which organisations can work effectively. This alignment can also co-ordinate ICT implementation in schools and participation in Olympiads and competitions. For example, if tablets are to be rolled-out into schools by the DBE, then it may be preferable for organisations to develop an application for their Olympiad or competition which is installed on those tablets. This can facilitate mass participation by a great number of learners. Having access to these types of applications can furthermore improve teaching and learning.

Alignment between government departments can ensure that training for host organisation staff and educators is focused and applicable. This also links to the role played by university staff and graduates, who may be able to conduct such training, discussed below. It may be possible that alignment across departments can afford internships or stipends to be offered for unemployed graduates who assist in the implementation of digital Olympiads or competitions. Finally, alignment will also allow for the use of pilot studies to evaluate implementation and assess the effects of digitisation on educator and learner participation, learner performance, comparability of test scores across digital and pen-and-paper assessments, and sustainability.

In terms of how **learners** can participate in an offered activity, **a hybrid approach** was recommended, where both digital and pen-and-paper versions are offered in parallel. This prevents exclusion if the relevant technological requirements cannot be met. Furthermore, once educators and learners are familiar with the material used in the Olympiad or competition, it may be possible to gradually introduce digitisation for educators and learners. A good practice identified in the results is to work closely with educators and allow them to lead the introduction of digitisation. This facilitates buy-in and furthers learners' participation. Additional good practices in utilising technology include:

- Adaptive platforms which can be accessed via desktop, laptop, smartphone, or tablet. This will allow for greater accessibility, as educators and learners have a wider range of devices which can be used. The caveat here is to ensure that the use of different devices does not introduce bias into the assessment. This can be considered at the item design stage.

- Techno-blended models (TBM) to allow access to the learning material both online and offline. This facilitates access for learners who may have intermittent Internet connectivity.
- Digitisation of learning content, such as PDF downloads, past papers, memorandums, and videos, as well as the formation of online communities of learning. This provides learners with access to a huge source of learning and facilitates the constructivist approach to learning. The latter approach enables learners to build on their personal experience, to take an active role in their own learning, and to use collaboration in the learning process.

It was noted that only multiple-choice questions are currently used, as they are easier to have in both digital and pen-and-paper format, can be marked by the software used, and place less strain on the connection to reduce the possibility of systems being slow or crashing. Thus, the hybrid approach may not be suitable for Olympiads or competitions which want to evaluate learners' critical thinking and problem-solving skills, which require open-ended questions and marking of learners' working out.

Sponsors are valuable role-players in the digitisation of Olympiads and competitions as there are costs involved in digitisation, for example, application development and human resources such as administrative staff, an application developer, and ICT personnel. However, many of the organisations which participated in this study noted that they have in-house expertise as well as volunteers who can assist. Identified roles for sponsors include:

- Assistance with software or platform development, management of the project, development of the items, and marketing.
- Assistance with equipment, venues, human resources or finances, which can help ensure that participation is free and thus reduces barriers to learners participating in the competitions.
- Sponsorships can also be in the form of human capital, e.g. internships for IT specialists.
- Assistance with provision of data. For example, MTN, Vodacom, Telkom etc. can set up connectivity for a group of learners who want to have access to the application and participate. The connectivity can restrict who can have access.

Another essential role-player is the **universities** and their staff and students. Universities themselves can act as a sponsor in various ways, as indicated above. However, universities are also valuable sources of expertise where their staff and students can:

- Assist in item development for the Olympiad or competition.
- Act as mentors for learners who want to take part.
- Act as trainers for educators and learners, particularly ICT students and graduates.
- Act as software developers for host organisations, particularly ICT students and graduates.

In conclusion, technology should be perceived as an enabler of the learning process, rather than as a silver bullet solution. In order to use technology for science Olympiads and competitions, solutions must be tailored to suit the readiness of the schools, and their learners, to adopt the technology. There is no ‘one-size-fits-all’ solution which can cover the huge diversity inherent in the South African context. Furthermore, all solutions must be designed with cognizance of resource and infrastructural constraints. A holistic view is essential and needs to incorporate multiple levels in creating solutions.

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