NATIONAL SCIENCE AND TECHNOLOGY FORUM

PROCEEDINGS OF A pro*SET* DISCUSSION FORUM

ON

STEM EDUCATION – DISRUPTIONS AND THE FUTURE

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Virtual online meeting

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DAY 1

WELCOME TO PARTICIPANTS AND INTRODUCTIONS; PROGRAMME, OUTPUTS, AND INTENDED OUTCOMES (MS JANSIE NIEHAUS, EXECUTIVE DIRECTOR: NSTF)

Ms Niehaus welcomed everyone to the pro*SET* (Professionals in science, engineering, technology) discussion forum. pro*SET* is a membership sector of the NSTF that represents over 40 professional bodies and learned societies.

While the excellent and inspirational science, technology, engineering and mathematics (STEM) outcomes in certain parts of the education system had to be celebrated, the enormous lack of equality in the South African education system, with the majority of schools being severely disadvantaged and many totally dysfunctional, made it difficult to ensure good STEM outcomes overall. Government's emphasis on the Fourth Industrial Revolution (4IR) provided opportunities to generate awareness about STEM education in the school system.

This discussion forum was about how to advance STEM education into the future and the disruptions caused by recent events, particularly the Coronavirus disease 2019 (COVID-19) pandemic. Those involved in STEM were incredibly concerned about the lack of a pipeline of skills in the system. The forum aimed to provide a platform for different perspectives, for comment on policy and to share best practice. The speakers would bring a variety of expertise to the discussions.

AWARENESS OF THE IMPORTANCE OF STEM SUBJECTS AMONG LEARNERS AND THE ROLE OF VUWANI SCIENCE RESOURCE CENTRE (DR NNDITSHEDZENI ERIC MALUTA, VUWANI SCIENCE RESOURCE CENTRE, HEAD: DEPARTMENT OF PHYSICS, UNIVERSITY OF VENDA, 2022 NSTF-SOUTH32 COMMUNICATION AWARD WINNER)

Vuwani Science Resource Centre was part of the University of Venda's (UNIVEN's) flagship programme on community engagement and one of several centres of the university. It was located in the community and within walking distance from several primary and secondary schools. The centre was established in 2000 and currently funded by the Department of Science and Innovation (DSI).

STEM awareness was important because it helped learners, especially those in rural areas, to understand the world around them and to get a glimpse into science and technology (S&T) and their role in solving problems the world faced. Learners had opportunities to work in teams, to communicate among themselves and with the public, to evaluate information and solve problems for themselves. The centre provided experiences in science that were entertaining, interactive, hands-on, relevant and understandable for learners. This was particularly important for learners in rural areas where the schools had no Science equipments or facilities. Learners were exposed to the basics of science through exhibitions, Science shows and other media, and were given the opportunity to visit other science centres and interact with other learners from other parts of the country.

An effort was made to identify learners with potential and guide them towards careers in science. Female researchers (MSc students from UNIVEN) from various fields of science visited rural schools to share their experiences as women in science, inspire young female learners to take Science as a subject at school and pursue careers in science.

The centre's activities supported the curriculum in terms of science experiments prescribed by the Department of Basic Education (DBE) especially relevant to Grades 10 to 12, and taught learners how to use laboratory equipment and do experiments. The centre also tried to improve learning and promote civil engagement through working with communities and addressing their societal needs and served as a platform for researchers to interact with communities through a variety of activities. As an outreach programme, the centre helped create partnerships between the community and UNIVEN. Engagements were through workshops, science exhibitions, National Science Week, the Eskom Science Expo and support to schools in terms of outreach and in-house activities and upgrading teacher training. Members of the South African Institute of Physics (SAIP) assisted educators regarding teaching content and skills that were beneficial to learners. The centre ran early childhood development workshops with educators to enable them to impart their knowledge to children at pre-school level and organised science rallies, women in science events, motivational talks and career exhibitions.

The centre collaborated with universities and other institutions nationally and internationally to bring awareness of STEM in rural areas and expose local learners to a wide variety of scientific disciplines and opportunities in science. Facilities at the centre included an exhibition hall and a computer lab. The lab was used to introduce learners to basic robotics and coding in collaboration with Nelson Mandela University (NMU) and the University of South Africa (UNISA). The exhibition hall provided a space to showcase life sciences, chemistry, astronomy and other science disciplines. Outdoor exhibits included a weather station and a solar photovoltaics (PV) system that were used to encourage climate change and renewable energy knowledge and awareness.

The promotion of science in rural areas required much more attention and learners and the public at large needed to be engaged to understand the importance of science in the context of their villages. Awareness of the sustainability of food, water and energy still needed to be addressed, especially in rural areas.

HOW TO TEACH LEARNERS TO BE INNOVATIVE? DOES IT MAKE SENSE TO INCLUDE CREATIVITY AS AN ASPECT OF STEM TEACHING AND LEARNING? (MS TSHIDI MORABI, SCIENCE, TECHNOLOGY, ENGINEERING, ART AND MATHEMATICS (STEAM) FOR KIDS EDUCATION)

STEAM for Kids accepted children from the age of 5 and exposed them to information technology (IT), technology and engineering. Children from limited resourced families were sponsored by the Lemek Foundation.

Incorporating creativity in STEM education required a mind shift, not only for children but also from the education perspective and the alignment of the curriculum with the STEAM framework. The introduction of the STEAM classroom served to stimulate and motivate and build confidence and enthusiasm through project-based learning.

STEAM was an interdisciplinary approach to education using different aspects of more than one academic discipline to examine a theme, issue, question or topic. 'Interdisciplinary' referred to bringing disciplines together under a theme while allowing each to remain distinct from the other. Students were allowed to explore through curiosity, play and hands-on learning with the aim of gaining real life experience in solving real world challenges. For example, children attending STEAM for Kids workshops gained a better understanding of their everyday experiences by learning to code a traffic light and a digital billboard.

The process of incorporating STEAM into the classroom involved selecting a topic, connecting the topic to a real-world problem, defining the challenge, applying an engineering design plan and media tools to explain the challenge, researching and brainstorming, creating and testing the prototype, communicating the findings and redesigning where necessary. This process could be carried out without the assistance of technology.

Interdisciplinary learning supported critical thinking by helping students understand multiple viewpoints, evaluate conflicting perspectives and build structural knowledge, and brought changes in the learning dynamics by placing students in much more active roles. Students could apply their critical thinking skills without the use of computers, for example, and this was particularly useful in rural areas.

It made sense to include creativity into STEM teaching and learning because it aimed to teach students the value of creativity, innovation, communication and contemplation. These skills were often in high demand in the workplace where creative solutions to problems were needed and where different perspectives were useful. Students applied the skills in various projects, such as creating a piano using different kinds of fruit to represent music tones instead of piano keys. They coded the programme, translated the coding into a microprocessor and linked it to the fruit. Each kind of fruit produced a different music tone. The students were also taught the skills necessary to be able to communicate about their project. Other similar projects were to do with virtual reality (VR) exploration and creating a robot from a cardboard box.

Incorporating the ‘A’ into STEM required doing away with traditional learning and adopting project-based learning using 21st century skills such as critical thinking to solve a problem, collaborating with other students to solve the problem, communicating and creating to come up with innovative ways to resolve the problem. Students accessed designing, building and technology skills through programming and project-based learning integrated the knowing and doing aspects. Students applied what they knew to solve authentic problems with intentions to produce results that mattered. One example was a course that taught students how to code a drone. This involved planning, designing, applying the geographical elements, engineering, technology and mathematics to be able to apply the end product in real life scenarios.

Some tips on how schools could implement STEAM education:

- Create teams of teachers with different subject expertise to plan STEAM lessons
- Adjust both student and teacher schedules to accommodate STEAM-based lesson plans, including time for planning, refinement and reflection
- Ensure staff and faculty received professional development in STEAM practices, principles and support.
- The STEAM approach had to be integrated into the curriculum and carried over from subject to subject.

School was no longer a place to learn but had become a learning experience itself. School did not have to be a place to learn, but rather a frame of mind that used the arts as a ladder to achieve explosive growth and social emotional connection, and to build a foundation for the innovators of tomorrow.

Q&A and Discussion

In response to a question about the financial implications of doing robotics in schools, Ms Morabi explained that STEAM for Kids taught students how to code, design and build their own robots so that they knew that this was doable. Assembling the actual robots would require funding.

Ms Niehaus commented that it was good teaching practice for learners to be involved in hands-on learning and solving real life problems. STEAM for Kids combined this with teaching skills for the 21st century.

Ms Sharanjeet Shan mentioned that the Maths Centre worked mostly in very disadvantaged schools and asked whether STEAM for Kids was able to offer free services by providing motivational speakers during the centre’s campaign called Youth^2 Daring to be Different. Ms Morabi indicated that STEAM for Kids would avail itself to the centre, adding that applying maths and science in real life scenarios would motivate learners to taking the subjects as part of the STEAM model.

Dr Thobela Nkukwana asked Ms Morabi whether she had approached the DBE about the possibility of incorporating STEAM into the curriculum for all schools. Ms Morabi indicated that the impact of the adoption of STEAM at two schools had to be evaluated and assessed before approaching the DBE in this regard.

Ms Shan mentioned that the Maths Centre had made a presentation to the DBE to acquire funds to purchase equipment to teach robotics (Lego EV3) but was unsuccessful. She suggested that the various centres should collaborate and share resources to reach as many disadvantaged learners as possible.

CHALLENGES IN MATHEMATICS EDUCATION FROM THE PERSPECTIVE OF A MATHEMATICS OLYMPIAD ORGANISER (MS ELLIE OLIVIER, SOUTH AFRICAN MATHEMATICS FOUNDATION)

Studies conducted prior to the COVID-19 pandemic showed that the South African education system was performing poorly and that learners were not meeting the grade expectations in many subjects including mathematics. Learning losses resulting from school closures and the rotational system that was implemented during the pandemic worsened the learning backlogs. The challenges within mathematics education were well documented and included overcrowded classrooms, teacher shortages, poorly qualified teachers, few matric distinctions and socio-economic challenges such as poverty.

The school curriculum was prefaced on the principle that a learner had to master the content of one grade to grasp the content of the subsequent grade. Learners who struggled with mathematics at school would have difficulty in solving the problems in mathematics olympiads and competitions because these problems extended beyond the classroom.

The main aim of mathematics olympiads and competitions was to promote the importance of and create a love for the subject. They were also useful for schools to measure their learners' mathematics ability against an external standard and could be used as a teaching resource. Many olympiad resources were available to schools and learners, including an online platform (mytutor.chat).

Participation in the mathematics olympiads and competitions helped improve learners' understanding of mathematics. A study that looked at primary school mathematics competitions between 2017 and 2020 showed a correlation between schools that participated in the competitions on a regular basis and improved performance in mathematics.

Problem solving had always been central to mathematics. Problems could be categorised as non-routine and routine. School mathematics papers presented learners with routine problems, which were rigid and repetitive, and focused on known procedures and rote learning instead of developing conceptual understanding and higher order thinking skills. Non-routine mathematics problems (NRMP) were found in the olympiads and competitions, and required creativity, originality, out-of-the-box thinking, critical thinking and reasoning skills to be solved.

Around 160 000 learners (from between 10 and 30% of all schools in South Africa) participated in the two annual national mathematics olympiads – one for high schools and the other for primary schools. Much more had to be done to extend the competitions' reach through cooperation with different levels of basic education. Teachers cited work pressure, budget constraints, their own struggles with NRMP and learners' difficulties with the papers as reasons for not participating in mathematics olympiads.

The pandemic had forced many educational service providers to move from face-to-face teaching to fully online teaching or blended teaching and to consider how they could use technology and integrate it into the programmes. Since 2020, the Mathematics Foundation had trained more than 2000 teachers using either a fully online model or a blended model of training.

Mathematics was one of the gateway subjects considered critical for the country's economic growth and development. Performance in mathematics was important for university entrance as school leavers without a matric mathematics qualification were not eligible for university programmes in science, engineering, accounting and economics. Learners who participated in the competitions were more likely to choose pure mathematics at the Further Education and Training (FET) level. It was anticipated that once a primary school learner chose to take taking pure mathematics, their improved mathematics problem-solving skills would also help them to achieve good grades in mathematics and ultimately contribute to a higher number of matriculants passing mathematics with a good mark.

The poor state of education generally resulted in mathematics being isolated in South Africa. Mathematics literacy was introduced for those learners who did not cope with pure mathematics at the FET level and technical mathematics was introduced in 2016. There was a lack of awareness among learners and parents about the differences between pure mathematics, mathematics literacy and technical mathematics, and the entry requirements for STEM related degrees at tertiary level. All stakeholders should play a bigger role in promoting the importance of pure mathematics for those learners who wanted to go on to study STEM related degrees.

The Mathematics Foundation made the following recommendations:

- The mathematics curriculum should be trimmed because it was too full and did not allow for in-depth study or time to pursue problem solving
- Regular participation in competitions was important to improve problem-solving skills and to ensure a good pass in mathematics
- Problem-solving skills would only increase in importance if the knowledge economy was embraced. In this regard, NRMP played an important part of learning mathematics
- Mathematics olympiads and competitions were therefore not only highly relevant to addressing the current key concern in the South African education system but would also equip learners to fare better in mathematics.

Q&A and Discussion

Mr Parthy Chetty commented that the real problem with regards to mathematics education was the focus on a pass rate, which was totally counterproductive, especially in the context of building a nation of critical thinkers and learners that would take STEM studies at university level. There were many cases of matriculants not being able to do engineering at university because they had taken mathematics literacy in Grade 12. This problem had to be addressed with learners as well as their parents. The onus was also on the district officers not to prioritise pass rate, but to focus on the learners.

Ms Olivier agreed with Mr Chetty, adding that a key concern was that since its introduction in 2016, more and more learners chose mathematics literacy over pure mathematics.

Dr Nkukwana agreed that the focus needed to shift from making sure that learners passed to developing critical thinking and problem-solving skills required at university level.

Dr Derek Fish found that the problems learners had often related to a lack of the basic concepts and that interventions were required at a much earlier stage.

Ms Olivier agreed that interventions should start when learners were young instead of waiting until Grade 12. There was some certainty that learners who performed well in mathematics olympiads coped well at tertiary level. The difficulties learners experienced with NRMP in mathematics olympiads reflected the broader problems in the schooling system, and these needed to be resolved.

Ms Shan suggested that a webinar should be organised to alert those involved in mathematics education in South Africa to the common misconceptions found in mathematics olympiads. Looking at the old papers and the solutions to the questions encouraged teachers to begin to understand the difference between routine procedures, complex procedures and problem solving as opposed to investigations.

Ms Niehaus indicated that the NSTF would consider providing a platform for such a webinar.

SA REPORT ON COVID-19'S IMPACT ON EDUCATION (COMMONWEALTH STUDY) (DR ANDREW PATERSON, INNOVATION AND RESEARCH SPECIALIST, JET EDUCATION SERVICES)

The research programme commenced in 2020 during the height of the COVID-19 pandemic when the need for research on the impact of the pandemic became evident for responsiveness and for generating better information and information that had specificity and usability to support decision making of education policy makers and on the ground. Much had happened since the research was done in 2020 and thematic waves of research had looked at the impacts on learning. The programme was developed with the understanding that many young researchers and students were confined and not occupied, and could therefore be encouraged to join the programme, which was largely conducted online.

JET developed a system where twelve themes of research were done, including finances, responses of government and civil society, use of curriculum and technology, education at home and teacher responses within the broad rubric of COVID-19 as an opportunity that could lead to improvements in schools to build back better. Parts of the programme were identified as relevant in the current circumstances.

The report was published in partnership with the Commonwealth Secretariat in 2021 and subsequently JET was commissioned by the United Nations Educational, Scientific and Cultural Organisation (UNESCO), Rhodes University and the Open Society Foundation to conduct another research programme.

Conclusions of one of the projects, which focused on assisting parents and care givers, were:

- Even the most highly educated care givers struggled with undertaking tasks with supervising or guiding school-going children in the home.
- It was important to support parents to engage positively with their children.
- There was a gap between parents and schools. Many parents needed guidelines to assist them and possibly a contribution from teachers on a regular basis.
- The internet was not the best way to communicate learning opportunities with school-going children.
- Even though there was substantial success with getting learning online, teaching and learning was more than about providing content. Learners, teachers and parents needed support in working with these resources, both in terms access to improving their familiarity with online resources and in using non-technological approaches.

The report covered other issues such as those related to the funding of education and access to the system. Scenarios were developed to explain the impacts on learners' scores to bring in several arguments around learner achievement and loss of learning. Access to learning and learning loss could appear differently in different contexts or occur at the same time. Attendance data showed the difference between no fee-paying and fee-paying schools, corroborating the previous point.

There was also information, especially important data, which reflected how the differences in learning loss occurred between grades and subjects, highlighting the need to pay attention to how the unique experience should be addressed. Looking at the various study methods and results, a lot had been developed since the early months when the only proxy of learning loss was missed days of school. It was important to understand these issues at the subject level, but also that most of the work focused on mathematics and languages. There was a lack of information on other subjects such as science at the same level of intensity.

JET data suggested that there was still a very important role to play for parents and parental involvement, especially after the lockdown period. It was clear from the research that parents were thrown into the deep end or into an emergency situation. This period of interaction was both daunting and very important for parents to immerse themselves, if they had the time and if they had the facilities available, to engage with their children's learning. The analysis presented showed that a lot of emphasis had returned to teachers and issues of assessment and accountability. This was critically important. Drawing from the early JET study it could be argued that there was a shift away from parents and care givers. It was important to encourage learners to return to school after they had left school under the pre-, during and after-COVID-19 circumstances.

Q&A and Discussion

Dr Paterson explained that JET was part of a non-government organisation (NGO) coalition that had met with the DBE and presented some of the general lessons learnt from the study.

Ms Shan pointed out that certain key factors had to be in play to bring about systemic change in terms of Mathematics. The research was crucial to understand that a national programme needed to be rolled out to acknowledge and recognise that parents were equal partners in their children's education.

Ms Niehaus proposed the idea of developing materials for parents to advise parents on how they could support the curriculum, adding that it would be interesting to know whether Science Centres involved the parents and if so to what extent and in what regard. Involving parents might be a very affective investment in STEM.

Dr Justin Yarrow suggested that guidelines could be given to School Governing Bodies (SGBs) to help bring parents into the conversation about their children's education, and SGBs could share best practices, guided by a process aimed at bringing in more parents.
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Dr Maluta mentioned that NMU had a relationship with the tribal authorities and engaged parents of students through this relationship.

Dr Nkukwana pointed out that although good ideas were put forward, involving parents from townships and rural areas in Science Centres, for example, would be a challenge.

Dr Paterson mentioned that there was pressure at different levels of the system and the relationship between parents and children was not as well developed as one would have liked. The idea of engaging parents was difficult to deal with but should be kept in mind even though it may not be regarded as the most important policy initiative to be taken up. The issue would remain important in the medium to long term and thought should be given to how this could be done in a way that generated value but not seen as just another thing to be done by pressurised teachers and school management.

EDUCATION TECHNOLOGY SOLUTIONS FOR REMOTE SCHOOLING (MR BEZ SANGARI, SANGARI SOUTH AFRICA)

Mr Sangari had been in the business of supplying education technology since 1982 and had always tried to come up with new ideas and systems, which were sometimes way ahead of the times.

E-learning was the greatest innovation in teaching and learning since the printing press. New technologies required a change in the way teaching was done. E-learning was a tool for self-study, collaborative learning, planning and analysis. Awareness and use of e-learning increased considerably during the COVID-19 pandemic. The basic methodology of e-learning involved asynchronous online courses, synchronous online courses and hybrid/blended courses. The components of the e-learning ecosystem were:
- Learner management system (LMS)
- Content management system (CMS)
- Collaboration tools, such as videoconferencing, messaging, digital white boarding and file sharing
- Productivity tools, such as email, calendar, note-taking, to-do lists, document creation and cloud calling.
- Content that provided correct, concise and accurate information in an easily digestible and memorable manner
- Digital simulations to provide an enhanced practical learning experience
- The dashboard, which was about monitoring and analytics and important for the teacher as well as the school management
- The teacher to guide learners and moderate content ('Flipping the Classroom').

Parents, whether or not they were educated, always needed to help their student children, but it was not always possible to do so. One of the strategies that many schools in the United States started to implement more than 10 years ago was 'flipping the classroom'. By using an e-learning platform, the teacher could simply post the lessons as videos or other content so that the students were able to learn the lesson as part of their homework, and then bring their homework into the class with a teacher who could help them. This strategy had continued to work very well.

There were many LMS providers who together with MS Teams/Google/Zoom and so on could provide the ecosystem required. Very few LMS providers had everything in one place. The dashboard analytics allowed teachers to prioritise their students' learning needs and was a tool to inform strategic teaching. It was critical for the teacher to be able to fully use the system and therefore, training and enforcement of use had to be part of the implementation. Content was very important as the entire e-learning platform would be useless without it. There were many content providers, and they were generally effective. There were also free websites, such as PhET Interactive Simulations, Khan Academy and millions of YouTube videos that taught on just about any subject. One of the best content libraries for STEM was from LJ Create.

In the past, learning was data driven but ought to have been task, object or project driven. Task driven learning was more like real life. E-Learning technology provided a high quality of content that could be taught in an entertaining way. People learnt quicker through play because it was more immersive and engaging and therefore more memorable. Many games and competitions, as well as online programmes supported STEM. CoderZ was an online learning programme that taught basic coding for robotics. Learning to code would become a basic requirement for most job applications in the future, but at this point in time, teachers could not be expected to be able to teach coding at any level. Online e-learning was the only tool to ensure that learners would be able to participate in the future economy. F1 in Schools was a different type of online learning programme. It was about a competition to build a Formula One model about 30cms long and shooting it down a track. Children collaborated in teams, registered for competitions, designed and built their model, marketed their product and participated in a world competition, all online. F1 in Schools also provided substantial STEM related online learning material that fitted into the school curriculum. Competitions such as F1 in Schools that used project-based learning incorporated a variety of skills including marketing, graphic design, art, time management and finances. Cross-curricular activities were inherently part of STEM projects and competitions. E-Learning had become a lot more accessible and now only required a computer and connectivity.

E-learning was essential for STEM because of the limited funding available for STEM and the critical shortage of mathematics, science and technology teachers, and because technology as a subject could not be taken beyond Grade 9 and was therefore not supported in most schools. To produce engineers for the future, it was essential to make STEM attractive and exciting to learners starting at primary school level. E-Learning and good content could make this possible.

Education was among the top five business sectors using chatbots (such as online tutors, student support, teacher's assistant, administrative tools for assessing and generating results) and in the not-too-distant future, educational needs of students would be available through Artificial Intelligence (AI). It was anticipated that AI would play an important role in the democratisation of learning and allow teachers to focus on helping learners. E-Learning systems should be used to implement new strategies for teaching and learning and make STEM learning 'Just In Time, Task Driven, and Cross-Curricular'.

Q&A and Discussion

Parthy Chetty and Lindi.Zikalala-Mabope (Zoom Chat): When we introduce new technology, we must spend sufficient time and resources training the teachers.

Gordon Branston (Zoom Chat): Thank you for the opportunity to comment on e-learning and to Bez for his insights. The envisioning process of what a future digital whole school approach looks like is considered critical to bringing the e-learning to fruition, including the cross-curricular implementation and the change step reconfiguration required by both the educators and management team - please can you point to the best-case studies i.e., research.

Sylvester Johnson (Zoom Chat): Future educators will have to face the fact that students will need (and want) to learn in a flexible, personalised format — for some, this may mean having a more technology-focused classroom. Students will want their learning experience to meet their interests, time constraints and academic needs. Very exciting times we are living in. The Future is Now.

THE PEDAGOGY OF TECHNICAL AND VOCATIONAL SKILLS: ROBOTICS AND BEYOND IN THE SOUTH AFRICAN SCHOOL CURRICULUM (DR IAN MOLL, SCHOOL OF EDUCATION, UNIVERSITY OF THE WITWATERSRAND)

Dr Moll present his argument about robotics and coding in the South African school curriculum, as styled in the Curriculum Assessment Policy Statements (CAPS) document, and a similar argument that applied to mathematics and science education more generally. His argument rested on two principles:

- The introduction of robotics and coding into the school curriculum was correct in principle and had to do with moving into an era in which an understanding of and working with the knowledge driven economy was important for learners to acquire.
- There was a policy construal of the robotics and coding curriculum that was a disaster from the point of view of understanding STEM education and what it needed to be doing.

The Minister of Basic Education's response to the question of the robotics and coding curriculum in parliament pointed to the curriculum being 'more skills focused than theory focused'. The teaching of skills rather than knowledge was a curriculum disaster. The amendments to the curriculum to accommodate these new subjects had dimensions associated with them at each level of the schooling system. In the foundation phase, young children would work with digital devices and robotic games to gain robotic skills. In the intermediate and senior phases, all learners would acquire robotic skills specified as output devices, automation, coding skills and so on. It appeared that children would be taught concepts rather than practicing or learning these concepts (learning by doing). Generic skills for digital technology and specific coding skills were specified for acquisition in the senior phase:

One of the ways of approaching the concept of skills and thinking about skills in psychology concerned the neuropsychological dimensions of skill, which started with an understanding of the different functions of the human brain and where they were located. The three areas of the brain each had different functions psychologically speaking and therefore in relation to the way skills were understood. The inner brain (or crocodile brain) was about the governing of instincts or emotions; the limbic brain was about feelings (cognitive representations of emotions and associated with motives); the neocortex was about complex cognitive constructions (internalise knowledge systems). These three areas operated simultaneously in the human brain.

The problem in the way that teaching skills in a school situation (including online education) was thought about was approached by looking at the brain and its different levels of understanding skill.

- Instincts or the emotional level of skill (the crocodile brain): Crocodiles only had emotions and nothing of a higher order, neurologically speaking. The inner brain of the human being was where their basic emotions or instincts were operative. There appeared not to be much by way of thinking about education and training purely at the level of instinct and it was not appropriate to think about education and training purely at the level of instinct. It was worth noting that there were conceptions of training that might be conceived of as operating entirely at the level of the crocodile brain.
- The affective level of skill (feelings as cognitive representations and motives associated with these) (the limbic brain): Skill and the training of skills at this level were very similar to giving an animal an edible titbit to get it do what was required of it. It was necessary to consider whether or not STEM education was successful at this level. The conception of skills training (the robotics curriculum being more skills focused than theory focused) was operating and understanding teaching and learning at this level of motive, the limbic system. Unfortunately, the way that the DBE seemed to be thinking about skills in the robotics curriculum operated entirely within the limbic and crocodile functions of the brain while knowledge, the cognitive construction level of skill, ought to be the focus in teaching robotics.
- The cognitive construction level of skill (feelings, the cognitive representations of emotions): This level was also about the socio-cultural construction of thinking and learning that took place in an education system and was where the robotics curriculum or any other kind of STEM curriculum, needed to be thought about.

Any skill, at whatever level, was always related to deeper knowledge systems and associated practices in those systems. Skills were not isolated entities that related only to a particular task but were carried out in relation to task in the context of a deeper underlying knowledge system carried within human psychologically. The use of tools in a skilled way was generated by a neural network of tacit procedural and propositional knowledge, which was always operative in relation to the exercise and the learning to exercise a particular skill. Thinking skills were generated by cognitive processes and executive control functions of the brain working together to encode novel information for future use. Critical thinking skills (such as problem solving, reflexive social collaboration) always involved underlying complex cognitive structures about ‘authentic practice in real world contexts’ or learning by doing. Scientific thinking involved ‘paradigmatic’ or ‘problematic’ knowledge systems situated in the learning about skills at that level.

When thinking about a curriculum for skills in relation to robotics for example, it was important to understand that skills were necessarily embedded in knowledge systems and were necessarily taught at that level of the neuropsychological system within which human beings operated, or the cerebellum, the cognitive construction of knowledge. This meant that because skills were anchored in this constructive knowledge context, it was necessary to avoid basic notions that broke skills up into bits and pieces and pretended that skills could be taught in isolation as atomistic bits and pieces of behaviour. Unfortunately, there were contemporary versions of these kinds of thinking that were very alive, in our midst and justified for example, in 4IR ideology and World Economic Forum (WEF) skills sets. Such notions reduced learning to the second level of neuropsychological functioning (the limbic system).

Skills were emergent psychological properties. They were emergent from socio-cultural and neurological processes that became psychological and related to the level at which robotic skills needed to be thought about and taught in the classroom and within the learning context in South Africa.

Teaching robotics was a form of teaching AI, which was a very complex discipline. One of the basic understandings within AI as a sphere of knowledge production was that robots would never be able to think like human beings. This was very important to understand, particularly for those who were learning about things such as robotics. It was very well known that robots were not capable of common sense, such as knowing that objects fell down and that something hidden behind something else still existed. After writing symbolic AI rules for all common-sense knowledge since 1984 and reaching only 5% completion by 2022, the realisation had begun to set in that Lenat’s “CYC Project” would be impossible to achieve.

There was also the understanding that human beings were not thinking machines, but feeling beings who think, and this referred back to hierarchies of cognition and neuropsychological understandings of skill. This thinking was associated with the very prominent neuroscientist and neuropsychologist, Antonio Damasio. A further level of the argument was known as the ‘Chinese Room Experiment’, a very prominent though experiment in AI as a discipline. The conclusion of that experiment was that robots could not have consciousness. In other words, they could not replicate thinking of human beings in the strong form that was sometimes expected by AI claims.

Narrow conceptions of AI were indeed possible. An algorithm could be written for a particular function of a human being, such as automation in the workplace. Strong conceptions of AI, within the discipline, had been shown to be impossible in principle. The problem regarding amendments to the CAPS document was that it did not actually work with these understandings of AI, which should be conveyed to learners when teaching them robotics and coding. Over many years, the point had been made quite strongly that any content could be taught to any child provided it was done in the right kind of formation, structural understanding of the knowledge, and provided to them at the right level.

Foundation phase learners could be taught about robotics skills by getting them to think about whether robots were alive like human beings, for example. There was very productive thinking in research that looked at this question in children at foundational level and found that very few children believed that dolls were alive. They could equally understand that robots were not alive in the same way that human beings were. However, a particular problem was encountered in children in the intersen phase. Their ideas about what robots were came from movies, for example, and needed to be dispelled quite thoroughly because they were completely fantastical. Industrial robots were not thinking machines and had been around since the 1960s. They were vaguely, if at all, intelligent. Anthropomorphic or humanoid robots developed in the last 20 years were very primitive machines with very few thinking skills based on weak algorithms.

There was nothing very revolutionary or that suggested some kind of major industrial revolution that was transforming robots in some way. When teaching robotics in schools, it was important to be very clear that the learners did not assume that robotics as they needed to learn about it for the economy was the same thing as robotics that they learned about in the popular images of movies and television programs. When teaching the generic skills in the secondary schooling phase, it was very important to teach the skills as embedded in knowledge systems.

Q&A and Discussion

Thobela Nkukwana (Zoom Chat): Industrial revolution is often linked to IoT and Big Data. I'm wondering if this is applicable in STEM learning and teaching, and how it can be used?

Tedson Nkoana (Zoom Chat): Matshidiso very interesting there, I use block coding but obviously very limited as the lines of coding are pre-written. It does however require some level of critical thinking as the lines have to be arranged in sequence to produce a desired command.

Palesa Mahlangu (Zoom Chat): Awesome @Matshidiso, great work you are doing out there, we also teach Coding and Robotics from grade 4-12, we are working on developing teaching and learning aids on the ABCs of Coding for ECD, id like to engage you

Gordon Branston (Zoom Chat): Resilience: A New Youth Skill for the Fourth Industrial Revolution - https://gbc-education.org/wp-content/uploads/sites/2/2022/03/Resilience-New-Youth-Skill-for-the-Fourth-Industrial-Revolution.pdf. The future of work is uncertain. The 4IR is set to fundamentally transform the way modern societies are organized, and technological advances - especially in artificial intelligence and automation - may lead to serious job displacement and skills shortages.

Gerda Botha (Zoom Chat): Could Dr Moll predict what the next stage of development in robotics (as a breakthrough) would be?

In response to Ms Botha's question, Dr Moll indicated that he was not a robotics scientist, but a historian of technology. To him, one of the most interesting and highly relevant developments in recent years in laboratory based technological development was the development of the bionic hand – an artificial, computer-based prosthesis that connected to a person's arm and translated electrical impulses from the human brain into electrical impulses that digital technology was able to read and therefore produce movement. The person could control the use of the bionic hand because of these technology developments. This was one of the cutting-edge transformations in contemporary technology taking place in relation to computerisation and robotics. This particular development would have all kinds of ramifications for other developments in robotics and so on. As Thomas Kuhn had said, the developments in science were not generally revolutionary, but normal Science as it proceeded in the laboratory context.

Ms Shan asked Dr Moll's view on the Fifth Industrial Revolution (5IR) and what he would replace the term with (for the purpose of schoolbooks). Dr Moll explained that the issue of the six industrial revolutions was a set of thinking about technological development that had come from the work of Carlota Perez and her predecessors going back to an Austrian thinker about the importance of innovation in technological transformation. This was a particular framework and not the same as the one about the 4IR and 5IR. When Carlota Perez talked about the first phase of technological development, she unfortunately gave it the label of the first industrial revolution and then talked about a further four technological revolutions. She did not expand the concept of industrial revolution despite the fact that she used the concept of the first technological revolution in the mid-eighteenth century. The discourse about the fifth and sixth industrial revolutions was in fact not about industrial revolutions but about technological revolution. Dr Moll argued that industrial revolutions were far broader than technological revolutions, which were about fundamental social transformations at cultural, social, geopolitical, colonial, neo-colonial levels, and that the right way to think about the 4IR was to view it as a deepening of the Third Industrial Revolution (3IR).

Ms Niehaus mentioned that the 4IR was part of government policy and as such needed to be engaged with. Her understanding of industrial revolutions was more about what happened to the workforce during economic transformation and although technological transitions might take place, they were revolutionary because of the widespread disruption and change they brought. It was difficult to distinguish between the fourth and the fifth and sixth industrial revolutions and it was also difficult to define them.

Dr Moll mentioned that it was important for government to respond to the ‘4IR’ in the understanding of it as a deepening of the 3IR. He added that Klaus Schwab had popularised the term and that the notion of a 4IR was ideological and there was no such thing as a concrete socio-economic phenomenon. Nothing had really been transformed by the so-called 4IR of the early 21st century that had transformed society and the economy and the nature of the workforce in the way that they were transformed by the 3IR. This was a historical argument that required careful scrutiny.

Ms Niehaus observed that the themes emerging from Dr Moll’s presentation questioned some and corroborated other issues that had been discussed by the speakers and participants. She reminded participants that two previous NSTF discussion forums had addressed the issue of the 4IR in relation to industry, society and education, as well as in automation and advanced manufacturing.

Ms Niehaus pointed out that there were different sets of skills: skills to master particular tasks (such as coding a self-drive car), skills that were basic to doing mathematics and science, and skills of communication (talking and doing presentations). Participants were invited to give their views about what ‘skills’ meant in relation to STEM education.

Ms Shan suggested that all the efforts made in schools were in terms of scientific process skills - hypothesising, observing, recording, learning to ask appropriate questions, oracy - as well as mathematics and science skills, such as making presentations, making inferences, making conclusions and so on. Understanding the basic skills in mathematics and science would motivate learners to take an interest in these subjects.

Ms Olivier suggested that to improve STEM education, it was essential to provide in-service and pre-service training to teachers. Government was mandated to do this. Teachers had to be equipped with the necessary skills and their content knowledge of STEM subjects had to be improved. Good quality and enthusiastic mathematics teachers were key to improving learners’ marks in mathematics and encouraging them to pursue the subject at tertiary level.

Ms Morabi’s view was that children needed to be taught basic skills and shown that they were capable of creating what they visualised without being intimidated by mathematics or science. At STEAM for Kids, children were shown a video of a self-driving car with all its elements and components. From this point, they were taught to code the car and saw the simulation once it was developed. This process taught children to understand that they did not have to be engineers to develop a self-driving car. Another approach was to show them chatbots and then teach them how to create their own chatbot. They were taught computational thinking and process thinking for the chatbot to be able to respond to written questions. The children were also taught about face recognition technology, how it worked and what the elements were and then they were taught how to code the technology. These children could become innovators because they knew what was doable and could visualise their ideas about what they wanted to create. When children started working with STEAM at a young age, they saw it as part of the lives instead of shying away from and feeling intimidated by the mathematic and scientific concepts of technology. Integrating the subjects and ensuring that children were given a cross-curricular, multidisciplinary and collaborative education helped them to decide how they wanted to apply STEAM in their lives.

Dr Moll asked Ms Morabi to unpack at a more detailed level the notion of showing learners a self-driving care by means of a video and then teaching them to code the car. Ms Morabi indicated that the coding language Python was being used as its libraries were helpful in teaching children to code. In the earlier stages, children were taught the basics and presented with ideas and possibilities around technology and coding. As they progressed, they learnt how to enhance the technology using their own ideas and to write algorithms themselves.

Dr Chetty pointed out that learners probably did not realise how the scientific skills they learnt at school translated to the workplace and the real world. For example, learning scientific skills would prepare them to make better decisions about something subjective such as buying a cell phone, by considering affordability and functionality, and analysing the facts to find the most suitable cell phone. Communications skills were often underestimated but essential in the real world to promote an activity, present to management and translate facts into tangible outcomes, for example. He emphasised that the huge void in linking learners with real scientists and engineers could be addressed by adopting a new approach to career development that would motivate learners to become scientists and engineers. Learners, particularly those in townships, should attend science camps where (young) scientists from a wide variety of scientific fields were invited to explain what they did.

Ms Shan mentioned that the Maths Centre had listed about 50 skills (and their meanings) that learners were taught and acquired around a scientific experiment and mathematical engagement. These were printed on posters that were placed prominently in the centre. She offered to send the list of skills to the NSTF.

Mr Tedson Nkoana highlighted the need for the most basic skills such as writing and presenting skills, which most learners seemed to struggle with possibly because they were not practiced enough at classroom level. It was the responsibility of those who were interested in learning outside of the classroom to engage learners more in activities that challenged them to write more and talk more to build confidence. These skills were necessary in the workplace and should be sharpened at an early age.

Ms Niehaus summarised the themes that had emerged from the day’s discussions as follows:

- Hands-on, active learning and learning where there was full engagement by the learners was preferable
- The importance of competitions and olympiads to facilitate active learning and to motivate, and of learning appropriate skills for science and mathematics
- The importance of the basic skills in science and mathematics to be able to advance, engage and participate in competitions and olympiads
- Cross-curricular, multidisciplinary, collaborative education (permeable subject boundaries) was essential to a child’s learning
- Technology as facilitator of teaching and learning addressed gaps in education, prepared learners for the future and helped to mediate the crisis in education, the lack of teachers and various other shortcomings in the education system.

DAY 2

WELCOME TO PARTICIPANTS AND INTRODUCTIONS; PROGRAMME, OUTPUTS, AND INTENDED OUTCOMES (MS JANSIE NIEHAUS, EXECUTIVE DIRECTOR, NSTF)

Ms Niehaus welcomed everyone to the second day of the discussion forum and recapped on the previous day’s proceedings. Certain themes had emerged from the presentations, namely:

- Critical thinking or evaluating information:
  - Ms Morabi referred explicitly to this.
  - Ms Olivier said that good mathematics education promoted critical thinking (a logical and analytical way of thinking)
  - Dr Moll demonstrated what critical thinking was and reminded participants of the importance of the social sciences.
- Engagement of parents:
  - Dr Paterson highlighted its importance
  - It was an ongoing problem that needed to be resolved to bring education on track.
  - Various participants confirmed the need to engage the parents and had ideas on how to achieve this.
- Inclusivity:
  - Making sure that rural areas were reached by initiatives in STEM education and that girls were included, as were differently resourced schools.
- Emphasis on inter-disciplinarity in terms of subjects and collaborations
- 4IR skills, digital skills, robotics and coding:

    - Several speakers addressed the DBE's amendment of the curriculum to include robotics and coding.
- Best practices in the classroom should include problem solving, group work, real life contexts
- Basic skills in mathematics and science were important
- Private sector initiatives were crucial.

Dr Moll had explained the neuropsychological dimensions of skill, pointing out that robotics and coding skills were being taught at the affective level of skill (the limbic brain) while they ought to be taught at the complex cognitive construction level of skill (the neocortex). This highlighted a clear policy issue.

DOING DIGITAL OFFLINE – CREATIVE SOLUTIONS TO BRIDGE THE DIGITAL DIVIDE IN SOUTH AFRICA (KEYNOTE SPEAKER) (DR DEREK FISH, DIRECTOR: UNIZULU SCIENCE CENTRE, UNIVERSITY OF ZULULAND)

Although the COVID-19 pandemic had disrupted education over the last two years, it also provided opportunities. Apart from many other problems in the South African education system, the digital divide made it simply impossible for many schools to participate in e-learning. The Unizulu Science Centre, based in Richards Bay in the KwaZulu-Natal Province, made sure that everything that was done was available to everyone without exception. The centre was almost 36 years old and had run matric workshops in rural venues for at least the last 25 years, attended by hundreds, sometimes thousands, of matric learners who were desperate to get assistance with their matric science and to take part in science experiments.

The matric learners needed the workshops more than ever during the lockdown period of the pandemic when the centre was closed to all visits from schools. It was at this time that the centre decided to undertake a project called the Essential Skills and make videos of the workshops. In 2020, each learner was given a booklet and the eight one-hour videos took them through the essential skills needed to prepare them for the exams, based on the principle that 'facts faded, experiments expired but skills stuck'. Examiners and the people who wrote the diagnostic reports recognised that learners managed the content but lacked the skills that were essential for matric and for life. South Africa desperately needed skilled matriculants.

The digital divide was a real problem. Most of the children that the centre wanted to help did not have access to computers and connectivity. Almost every school had a device of some sort but almost none of them had internet of a quality that allowed them to stream live or download videos. The centre decided to physically distribute the videos and other resources to schools on flash disks. In addition, 5000 booklets were printed and distributed to matric science learners at 180 high schools in the local district. The SAIP helped with funding that allowed the centre to print another 20 000 booklets and make another 1000 flash disks that were distributed to learners in a neighbouring district as well as three other provinces. Currently, the video project was being used in all nine provinces and had been distributed to 80 000 learners to date using funding from SAIP and South32.

The videos were not meant to be used to teach a section of the curriculum, but to revise a section once completed. Theory was presented in very innovative ways using simulations such as those from PhET in an interactive way, making the lessons much more interesting than the PowerPoint presentations. The theory was also summarised using colours, illustrations and other graphic effects. Strategies were provided wherever possible, for example for problem solving, and examples were given of the experiments that were shown in the videos. Leaners were fully involved in the experiments but could not touch the apparatus. The simulation of the photo-electric effect was an example of the many very helpful simulations available from PhET. The simulations could be used just as effectively online as live in the classroom. All the tools were downloaded onto flash disks, which were made available to teachers so that they did not require internet connectivity to teach.

It was unfortunate that Grade 12 learners, who were technically at their intellectual height, spent most of the year doing revision in preparation for the important matric exams, because there was no time left for them to apply the theory in real life contexts. Data and graphs were not only essential for science but for everyday life. It was a tragedy that many learners knew how to manipulate the photo-electric effect yet had never even seen pictures of solar farms, solar powered aeroplanes and the International Space Station, which was powered by an extensive array of solar panels. It was so important for the stories of science to be told in the real-life context.

The previous three years' matric exam papers had been carefully analysed to identify the specific skills that learners needed. Once they had learnt the specific skills, learners were shown how to answer the various types of questions using those skills by looking at examples in the booklet and in the videos. At the end of each video there was an interview with someone who was active in the field, and there was a discussion about the matric exams, to try to encourage learners to aim higher than the minimum required to pass the exam.

Implementation of the Essential Skills project started with the concepts, the content, the skills and the exams, feeding these into the booklet and making PowerPoint presentations, and then recording the videos, which were very good quality but small file size (2 MB per minute) because data was an issue.

The project also looked at what section of physics was taught in which month in Grades 10, 11 and 12, and teachers were encouraged to address the different sections at appropriate times.

An evaluation of the project's implementation in 2020 revealed that more needed to be done and the centre had subsequently committed to extending the project to include essential skills for physics, life science, chemistry and algebra.

The centre found digital videos to be advantageous in the following ways:

- Learners all over South Africa benefited
- Small learner groups
- Short, one-hour sessions
- Workshops took place in schools
- No time out of school or disruption of classes
- No extra exposure to COVID-19
- Educators were free to answer learners' questions
- No venue hire or travel costs for the centre
- Centre staff were saved from exhaustion
- Experiments always worked on a video.

The main challenges faced by most South Africans in respect of e-learning were the lack of network and connectivity, and the high data costs. None of the quintile 1,2 and 3 schools in Zululand would be able to connect to workshops as the internet was not stable and an 8GB download would cost them considerably more in terms of data than a flash disk. Offline videos did not require connectivity and scheduling, nor did they incur data costs. The videos could be paused to allow for practical application, explanation and discussion in class. The disadvantages of using videos were the absence of personal contact between learners and teachers, the costs of making the videos, flash disks and physical distribution (if not sponsored), and the materials required upgrading. The materials were also available online through various portals.

Going online was a big issue for most people in South Africa but digital did not have to be online. The centre's videos were used in two other projects:

- iNethi, a project taking place in Ocean View in Cape Town, that was a community owned network, centred at the high school with various wireless repeaters throughout the community. The entire township (10 000 people) had access to the wireless LAN (100MB per second, zero data costs) and to resources without ever going onto the internet.
- The Golden Future project addressed the challenge of lockdown tutoring and connectivity constraints. A WhatsApp based system was set up, requiring very little data, to facilitate communication between students and tutors including the Essential Skills videos.

Dr Fish could be contacted at FishD@unizulu.ac.za or thefish@iafrica.com.

Q&A and Discussion

Dr Christine Steenkamp asked if the material could also be used for teacher workshops, for revision and upskilling purposes. Dr Fish said that he had done teacher training all over the country through the series of SAIP teacher workshops. The 16 videos formed the bulk of the material on flash disks, which also included all the physics exam papers going back to 2014 when CAPS started, extra programmes (teacher resources), a set of skills for life sciences and all the PhET simulations as well as SAIP resources.

Mr Nkoana mentioned that a Youth STEM programme for schools had recently been started at the University of Pretoria using existing resources. The centre’s offline videos (on flash disk) had been implemented, but learners needed advice on how they should make full use of all the material on the flash disks.

Dr Fish explained that teachers were given the flash disk and a teacher demonstration model was applied. Children who had laptops were encouraged to download the resources on the flash disk. Numerous videos were available on the Essential Skills Facebook Page and PhET was busy translating their simulations into African languages and was looking for translators to assist in this regard. He suggested to the NSTF that the issue of language and science was worth a discussion.

Dr Fish had been awarded a Fulbright Scholarship to spend a year studying at the Institute for Learning Innovation in the US working with John Falk, an expert on Museum Studies, to develop a cadre of researchers in ‘informal/free-choice learning’ that would commence in South Africa in 2024.

Ms Niehaus assured participants that links to the material referred to by Dr Fish would be available on the NSTF’s website.

CAREER GUIDANCE AND AWARENESS OF THE IMPORTANCE OF STEM (MS KGAUGELO PULE, STEMULATOR RESEARCH ASSISTANT, NSTF)

The STEMulator was a free online tool (https://stemulator.org/) used to stimulate young minds to become curious about STEM. It was made up of a series of tiles covering topics such as nature, energy, the hospital, the home, the human body, agriculture, architecture and construction, factories, transport, aerospace and science. It was designed to operate on a variety of platforms and devices to reach the most remote areas of the country. The STEMulator, loaded onto a flash disk, was given to teachers as a tool to teach STEM subjects. The NSTF gave demonstrations of the STEMulator during career expos and outreach events.

South Africa was known to be one of the four lowest performing countries in Sub-Saharan Africa in STEM at tertiary level, with only one in ten high school learners deciding to pursue a career in STEM. The world was becoming increasingly digital and the demand for skilled workers in STEM jobs had rocketed in recent years. It was essential to encourage more learners in South Africa to focus on STEM subjects. STEM education had become more important than ever, particularly when combined with a broad range of knowledge that included the arts, communication and social sciences to better prepare young people for the real-life application of knowledge.

Access to degrees in STEM subjects at tertiary level was reliant on top marks in matric math and science. This meant that math and science had to be promoted at primary school level and that high school learners had to be encouraged to choose pure math over math literacy at matric level. The NSTF had made a series of brief videos introducing prominent scientists to inspire learners and help them understand how STEM subjects were applicable in real life contexts. The NSTF also had a career booklet that provided information about over 40 STEM related careers. Teachers were given the hardcopy as well as pdf versions of the booklet (on the flash disk together with the STEMulator) to facilitate sharing of the information with learners.

Demonstration of the STEMulator (Mr Richard Gundersen)

The STEMulator had grown out of a career guidance poster and a dream to build a 'game' made up of various elements (fields of STEM) in a real-world landscape. pro*SET* decided to undertake the project and begin by populating ten main areas in the STEMulator. The starting point was the car. When clicking on the image on the relevant tile, the relevant page revealed all the components of a car with labelled diagrams and animations of the moving parts. A short text gave the basic information about the car and clicking on the 'x^2' icon led to maths equations relating to a specific aspect of the car, such as the volume of a cylinder and the compression ratio of an engine. Logos of organisations associated with the STEMulator could be carried on the page, and when clicked on, would lead to more information. Once the STEMulator's relationship with Wikipedia was formalised, the icon would lead to the more detailed text available in Wikipedia. (Features such as these would require internet connection.) In addition, a video, curated from content available on the Web, also introduced some aspects of the car. Links on the page guided one to details about careers closely linked to the car engine and to the homepages of institutions where the relevant qualifications could be studied.

You Tube videos consumed 200 to 500 MB of bandwidth. To overcome this problem, content in the form of compact GIFs (around 28 kilobytes each) was loaded onto the flash disk. Much effort had been put into finding content that belonged in the general interest and was of educational value. More ideas had come to the fore as the project progressed, such as the inclusion of a timeline that followed the agricultural process of farming wheat all the way to a loaf of bread in the home. The school tile was currently being designed and developed and would cover the full curriculum in the math and science classrooms for different age groups.

Partners were sought to help contribute content to the tile on mining. Other tiles that were currently being populated included an animal world linking various animals to their actual habitats, a science centre, a museum including a herbarium that would accommodate collections 'donated' by South African National Biodiversity Institute (SANBI), divisions on transport, geology, the military and robotics, a planetarium, an exotic bookcase and an observatory.

The idea was for the platform to be for free, with no advertising, available worldwide, thought of as Wikipedia, convenient, well laid out, interconnecting and appealing to navigate. Sourcing material was a time-consuming exercise and content contributed to the stimulator to enhance it would be gratefully accepted. There was scope for the STEMulator to be enhanced for use for psychometric testing for career guidance purposes.

The pro*SET* Committee had embarked on a relationship with a few of the professional societies within the NSTF and pro*SET* to share material that described concepts to guide children in the direction of STEM and expose them to new ideas and concepts and generate a new level of enthusiasm and interest in those subjects.

Q&A and Discussion

Ms Niehaus explained that the STEMulator was a pro*SET* project and as such, pro*SET* was responsible for overseeing the project and had provided the initial funding for the project. An appeal had been made to NSTF members to provide content to the STEMulator, and the South African Institute for Industrial Engineers had agreed to populate the factory tile, KPA Engineering was contributing to the content of the transport tile, the Corrosion Institute of South Africa had contributed, and the Water Research Commission's (WRC) material on various aspects of water management would be contributed to the STEMulator.
Ms Pule pointed out that the museum tile would have a division for robotics and a division for coding, and both would be added to the school tile as part of the curriculum.

Ms Botha, on behalf of the pro*SET* Committee, invited participants to offer advice on the project, particularly regarding aspects for additions and directions to take.

Derek Fish (Zoom Chat): Would love to see the Essential Skills videos included on the STEMulator (and the STEMulator included on our memory sticks!)

Gordon Branston (Zoom Chat): Thank you for this stimulating presentation. I would like to enquire on the emerging opportunities to develop and test ideas on how to implement the Sustainable Development Goals (SDGs) in STEM lessons. The following link provides future opportunity that aims to create concrete and hands-on teaching concepts that encourage students to become active and responsible citizens while promoting their interest in STEM subjects. The teaching materials "Act Now for the UN Sustainable Development Goals" will be published on 14 October 2022. Thank you https://www.science-on-stage.eu/project/act-now-un-sustainable-development-goals.

Ms Pule indicated that the NSTF would be happy to discuss the issue raised by Mr Branston and Ms Niehaus added that reference could be made to the SDGs in the relevant STEMulator tiles.

STEM EDUCATION INNOVATIONS IN TEACHING STEM SUBJECTS, PEDAGOGICAL CONSIDERATIONS AND IMPLICATIONS (DR KGADI MATHABATHE, DEPUTY DIRECTOR: EDUCATION, UNIVERSITY OF PRETORIA)

As the future workforce, students were the key stakeholders in STEM education. A new generation of students, or Gen Z (born between 1995 and 2010), were currently entering tertiary education and consideration had to be given to approaching STEM education in a new way. It was often stated that Gen Z students were underprepared for university, but perhaps the point should be about whether universities were prepared for them. Some of the questions that needed to be pondered on were:

- How would STEM teachers and teacher educators, those who trained teachers, deal with the characteristics and learning styles of Gen Z students keeping in mind the vast differences in characteristics and learning styles between them and students from previous generations?
- How would teaching and learning practices be affected in trying to accommodate this new generation of students?
- What were the implications for STEM education in schools and universities?

The characteristics of Gen Z closely resembled those of Millennials, who were described as confident, particularly in the use of technology, hopeful-optimistic, inclusive, goal and achievement orientated, and civic minded. Their learning preferences focused on technology, entertainment and excitement, teamwork, structure and experiential activities, and electronic modes of communication and communication that was positive, respectable and respectful, motivational and goal focussed. These characteristics presented opportunities to adapt the strategy for teaching and learning to incorporate, for example, electronic communication and interaction, experiential and authentic learning experiences, group activities, setting goals, providing feedback and community related learning.

Technology could be used to reach out to Gen Z students, and they could easily be immersed in VR spaces to enhance experiential and authentic learning, for example. Gen Zs were team oriented and liked to stay connected, which allowed them to work together and tap into each other's strengths. They were frustrated by delays in response times and a lack of structure or order. Being goal and achievement orientated meant that gaming was useful to create authentic learning experiences and provide goals for them. This urged teachers to become more explicit about the learning outcomes of specific activities. Gen Zs treated others with respect and expected the same in return. Teaching and learning strategies ought to provide opportunities for community engagement as part of a holistic curriculum.

Catering for Gen Zs meant that effective teaching could not be about the transmission of information and memorising facts as these would not prepare students for a dynamic and constantly changing work environment. Although information could be transmitted, students created their own knowledge (understanding) through authentic experiences of learning. What was taught was not what students understood. It was necessary to create opportunities for students to build on their own prior knowledge and to develop their thinking skills, to help them to become adaptable and flexible and to evolve as and when necessary. Opportunities needed to be created through technology and in-person interactions.
Class time should be used for meaningful engagement. Every university used a version of the flipped

teaching and learning model, which encouraged students to prepare before class. Post the COVID-19 pandemic, students had returned to campus but needed a reason for having to be in class. Teaching staff had to be supported in terms of the technologies available to make class time as well as the after class (the consolidation period) more meaningful.

One of the teaching approaches followed was inquiry-based learning or teaching, which also had to do with the pedagogical content knowledge and the technological knowledge needed to strengthen pedagogical reasoning, and the choices made in terms of the teaching tools used. To prepare students for an unpredictable future, teaching had to cut across all the paradigms of education: transmission, transaction, transformation and transcendental, with the aim of confronting students with real life or simulated challenges that they had to resolve to develop their problem-solving skills through being exposed to either authentic or virtual environments.

An example of this was a scholarship of teaching and learning project that facilitated BSc chemistry students' development of a professional identity as chemists during the early stages of their studies. The brief given to the students used a simulated context-based approach requiring the students to experiment and explore different routes of synthesis, evaluate the routes and choose the route that met criteria that infused education for sustainable development, technology and cost-effectiveness. They had to develop an executive summary for presentation to a hypothetical board for grading purposes. This simulated industrial project used a learning technique that addressed the need by Gen Zs to work in teams and helped create a safe space for skills such as planning, practical investigations, problem solving, communication, and for metacognition reflective skills to be developed. A scaffolding approach was applied over a four-week period, gradually reducing the number of instructions given to the students and presenting the material or the instructions for synthesising the compound in a journal-type abbreviated manner during the last four sessions. Students were provided sufficient preparation time to ensure that detailed planning was done. Reflective learning questionnaires were intentionally introduced at each point along the process to help students think about what they were doing and provide them opportunities to revise their strategies.

The findings were:

- The collaborative work elicited a lot of discussion, providing opportunities for the students to reflect on their thinking, organise their explanations and arguments in a way that made sense to their peers and make their thought explicit.
- The students felt better prepared for the laboratory having actively participated in planning their own investigations.
- The technical skills were also developed in the process while developing the softer skills such as metacognition and understanding.
- The students engaged with the practical work at a deep intellectual level demonstrating that contextualised inquiry-based laboratory teaching afforded an improved quality of learning.
- The reported practical curriculum made a very difficult subject more accessible and popular, and to some measure grew the students' ability in all desired graduate attributes, resulting in a professional identify for individual students.

Recommendations were:

- It was necessary to continuously revisit the curriculum and align it with teacher training, industry and societal needs including issues around entrepreneurship, education for sustainable development, 21st century skills and the responsible use of technology.
- Learners should be provided more support in terms of preparing them for university through pre-university programmes that enabled them to experience the content and the STEM in a non-threatening way to encourage STEM literacy.
- STEM educators needed to be capacitated, both pre- and in-service, and through professional development opportunities, exposure and partnerships
- STEM teacher education needed to model the approach to teaching that was wished for the classroom.

In terms of STEM education, it was important to experiment with different approaches such as inquiry-based teaching, self-regulation learning, process oriented guided inquiry learning (POGIL) and systems thinking and adopting a growth mind set.

Q&A and Discussion

Ms Niehaus commented that the point was often made that teaching had to be appropriate for technology, a changing society and the types of careers that young people followed. She asked what the implications of this were for school classroom teaching, and whether any of the findings and recommendations presented by Dr Mathabathe could be implemented at school level.

Dr Mathabathe indicated that lessons learnt from the project she referred to in her presentation could apply to schools, especially at the pedagogical level and given Gen Zs' natural ability to work with technology. The pedagogy provided an opportunity to develop the skills, the knowledge and the values. For example, POGIL allowed the teacher to move from the simple and familiar to the abstract, demonstrating concepts in a non-threatening way.

Ms Niehaus pointed out that systems thinking was valuable in analysing any situation but was not part of the curriculum. She asked if there was material around cultivating systems thinking or approaching situations holistically that was suitable for schools. Dr Mathabathe indicated that the literature and resources were available on Google Scholar, particularly since there was a growing interest in this topic.

Ms Shan mentioned that thinking had moved from Newtonian thinking to quantum thinking in the past four or five years. The Gordon Institute of Business Science (GIBS) had done some of the best work in systems thinking and offered courses on the topic. There were many very good examples of systems thinking in real life that could be adapted for use in schools. Teaching maths across the curriculum, brought in systems thinking automatically. A few years ago, the Maths Centre undertook a project that looked at mathematics in the environment and climate change, and brought geography, maths, science and life orientation teachers together to explore the issues. A kit on the environment across the curriculum was produced as an outcome of the project. It was unfortunate that maths was not looked at across the curriculum in the South African education system.

Ms Niehaus mentioned that the DBE had indicated the intention that children ought to engage in project work, specifically in mathematical modelling.

Ms Shan mentioned that the centre engaged in a lot of project work through a campaign called STEAM for Engineering, which brought in mathematics, science and technology. The project design always had to connect to the community, and this brought in systems thinking.

Gordon Branston (Zoom Chat): Thank you for explicitly highlighting the pathway towards a whole of society approach with reference to the SDGs and systems thinking - It reminds me of a research paper with substantial contribution from a well-respected SA academic …transitions require "… a more systemic and reflexive way of thinking and acting, bearing in mind that our world is one of continuous change and ever-present uncertainty. This suggests that we cannot think about sustainability in terms of problems that are out there to be solved or in terms of 'inconvenient truths' that need to be addressed. Instead, we need to think in terms of challenges to be taken on in the full realization that, as soon as we appear to have met the challenge, things will have changed, and the horizon will have shifted once again." Transformative, transgressive social learning: rethinking higher education pedagogy in times of systemic global dysfunction – Heila Lotz-Sisitka.
https://www.sciencedirect.com/science/article/pii/S1877343515000822?via%3Dihub

Mr Branston mentioned that he had recently taken a course in education for sustainable development through Gothenburg University. The pedagogy around systems thinking and the critical importance of introducing that to teachers was one of the projects he was involved in. The project proposal was essentially aimed at primary schools. The proposal put forward a transformative, reflexive, whole primary school, and ultimately a community co-learning approach to learning for sustainability by using plastic dinosaurs to introduce systems thinking and the SDGs. The way that the project unfolded was to deconstruct, in this case, a dinosaur made from plastic. It captured the imagination of young people because it was a huge, very ferocious animal that could be compared with things such as consumerism. This gave teachers the opportunity to engage with very young students who were able to make those connections by working with a plastic dinosaur. Deconstructing a dinosaur into its many parts could help move into a digital, virtual world using technologies, but also into the manufacturing process and social justice issues. Systems thinking was a critical skill and incredibly useful but was not taught at schools. Teaching reductionist thinking, even in the context of academic studies, meant that multidisciplinarity was lost. Mr Branston offered to send the project proposal to the NSTF.

Sylvester Johnson (Zoom Chat): Today's problems come from yesterday's “solutions.” “Quick fix” solutions of today can make problems and more stress in the future. Personal mastery, mental models, building shared vision, team learning, and systems thinking is so needed, even at school level.

CREATIVITY AND STEM EDUCATION (REFERRED TO AS STEAM) AND OPEN EDUCATION RESOURCES LINKING TO CREATIVITY (MS KATHRYN KURE, CEO: STEAM FOUNDATION NOT FOR PROFIT COMPANY (NPC))

Ms Kure recalled that her young son was adamant about breaking things because he believed that this was how he learnt how things worked. The world today was experiencing many problems because of humans breaking things, such as the environment. It was in the middle of the Anthropocene era, industry was creating mounds of waste, indigenous knowledge systems were disrespected and disregarded. Research done at the University of Essex had recently shown that pyrocumulonimbus clouds were directly responsible for the massive global warming of the last year in Europe. Unexpectedly, Big Pharma was mistrusted in the COVID-19 pandemic, with a proportion of people refusing the vaccine. Democratic governance was under threat. The information war made it easy to hack the voter not the votes and alternative facts were on the rise. The concept of education and joblessness was being rethought in terms of the 4IR and the digital divide put pressure on South Africa to catch up with the rest of the world.

Recapping on the presentations made on Day 1, Ms Kure remarked as follows:

- She did not disagree with any of the methodologies looked at, the collaboration, project based learning and other aspects relating to the question posed by Ms Morabi about whether it made sense to include creativity as an aspect of STEM teaching and learning.
- She emphasised that robotics was inherently about dealing with objects in the real world and involved basic science and mathematics. Successful teaching and learning of the discipline required collaborative thinking and interdisciplinary work.
- Regarding the factors contributing to the struggling education presented by Ms Olivier, she added the digital divide, inequality, unemployment, decision fatigue, teachers teaching out of subject and lacking confidence.
- She concurred with the point made by Dr Moll that there was no mind without emotion and humans were feeling machines that think. Predicating this as the basis for understanding how to apply, within an education system, what was learnt would bring a different approach and the question about adding creativity into STEM would presume a divide (mind versus body, man versus nature, science versus art, logic versus emotion). Humans were inherently creative, but easily crushed.
- She pointed out that the first industrial revolution was an almost inevitable consequence of a leisure reading Bourgeoisie. The modern education curriculum was created by people who were terrified by women reading and writing romances and therefore, the modern education curriculum was originally devised as a curriculum for women and became a general curriculum because in those days one studied Latin, Greek and Mathematics at university. This was one way in which the modern education system was a consequence of the first industrial revolution.

The ‘6 Cs of education’ (collaboration, communication, content, critical thinking, creative innovation and confidence) were interrelated. Creative innovation needed to be rooted in the soil of collaboration and have a network of communication, content, critical thinking, creative innovation and confidence. Functional magnetic resonance imagery showed that exactly the same part of the brain lit up for both ostracism and pain. The mind and body were fully interrelated. Social media was about a deep sense of belonging and being socially connected was the brain's life-long passion. At some level, humans were remarkably predictable and vulnerable. They were drawn to want to have simple answers to complex emotional issues. To impact a classroom, it was fundamental to work with the teachers and make sure that they themselves experienced a safe space and had cooperative learning. Certain things, such as crowded classrooms, could not be changed, but tools could be provided to help teachers to handle them.

Teaching could learn lessons from advertising. Print advertising had extremely clear trends, which had to do with how the brain perceived things, such as the use of large letters and bold colours. Imagery and creativity, likability, humour and belonging were predictors of performance in advertising. Teaching, like advertising, required repetition to convey a message and had similar predictors of performance.

There was no doubt that creativity had to be included in STEM, but this would mean that there had to be psychological safety within the classroom and that teachers had to be provided with scaffolding to help them build confidence that would enable them to teach. The STEAM Foundation gave teachers materials to support them in this regard. It was difficult to model cooperative learning or collaborative learning with the limitations of digital tools, but the materials provided the recipe and ingredients for success.

Fundamental cooperative and collaborative learning techniques involved the creation of heterogeneous groups that were important for collaborative learning the roles allocated to those in the groups. Tasks could not be completed unless each person had a specific role with associated goals that encouraged co-dependence. These important techniques helped break down the barriers. Time had to be spent on creating a group identity. Initially, little tasks were set to create social cohesion within a group. These techniques were powerful in enabling people to see others as people. Teams that flourished and thrived were those that had a sense of psychological safety. They knew that they were seen and valued. Creativity would not be possible unless this formed the basis. Cooperative learning techniques were profound and there was pushback especially from those head of schools who expected children to sit quietly at their desks during class.

The approach focused on keeping data usage low, which was critical. Even though open educational resources were thought of as necessarily digital, an open educational resource could be anything and in reality, there were very few properly licensed open educational resources. South Africa used the UNESCO definition of open education, which stated that releasing material without copyright so that it could be adapted and used for non-profit purposes for free allowed for accessibility to the content. The context of fair use had to be changed in South Arica's Copyright Act. Educational resources that were funded by taxpayers should be open, but currently, much of the resource was behind a paywall or a registration wall and almost all open education resources were subject to copyright because they were not licensed as open access. While universities were fully onboard regarding open education resources, the basic education sector struggled with systemic issues, which would need to be addressed.

Q&A and Discussion

Dr Moll thanked Ms Kure for her fascinating insight into the origins of systematic education in the first industrial revolution that related to the education of women and would take the discussion further with her.

Ms Shan had a particular interest in cooperation and collaboration, as proposed by Ms Kure, which needed to be translated in the classroom. Consideration (of each other) was critical and should be added to the '6Cs of education'.

The forum supported the following recommendations that were proposed as an outcome of the discussions to be put forward in a letter to the DBE:

- The inclusion of robotics and coding in the curriculum was necessary and correct, whether as separate subjects or part of a broader curriculum. However, there was a concern regarding how it was being construed as an interpretation of policy, particularly in terms of the way it seemed to be unfolding in the classroom, at the level of district offices, university technology researchers and so forth. The policy was located in a conception of skill that was too narrow and too technicist.
- The connectivity problem was completely pervasive, and the digital divide had increased during the

pandemic and other disasters. Urgent intervention was needed to address the matter.
- The 30% pass mark for STEM subjects at matric level was not acceptable.
- Offline digital materials were funded by private sector donors and as such were unequally distributed to schools across the country. Support was needed to make these resources available to schools throughout the country.
- Regarding the implementation of policy to practice, there was a need for a planned progamme of (online) training for heads of NGOs, district directors and subject advisors in any new digital programmes that were being rolled out.

CLOSING

Ms Niehaus thanked the audience and speakers for their participation in and valuable contributions to the discussions, and reminded them that all the presentations, recordings and proceedings of the two-day event would be available on the NSTF website, and a media statement summarising the issues that were discussed would be released soon.

ANNEXURE A: LIST OF ACRONYMS

3IR	Third Industrial Revolution
4IR	Fourth Industrial Revolution
5IR	Fifth Industrial Revolution
AI	Artificial Intelligence
CAPS	Curriculum Assessment Policy Statements
COVID-19	Coronavirus Disease 2019
DBE	Department of Basic Education
DSI	Department of Science and Innovation
FET	Further Education and Training
LMS	Learner management system
MB	Megabyte
NGO	Non-government organisation
NMU	Nelson Mandela University
NRMP	Non-routine Mathematics problems
NSTF	National Science and Technology Forum
POGIL	Process oriented guided inquiry learning
pro*SET*	Professionals in Science, Engineering and Technology
SAIP	South African Institute of Physics
SDG	Sustainable Development Goal
SGB	School Governing Body
STEAM	Science, Technology, Engineering, Art and Mathematics
STEM	Science, Technology, Engineering and Mathematics
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNIVEN	University of Venda

ANNEXURE B: LIST OF ATTENDEES

Title	Name	Surname	Organisation
PARTICIPANTS			
Dr	Tebogo	Mabotha	Academy of Science of South Africa
Ms	Rajeshree	Mahabeer	Academy of Science of South Africa
Prof	Himla	Soodyall	Academy of Science of South Africa
Miss	Sherrie	Donaldson	African Innovators
Miss	Nolubabalo	Ntunzi	AGES Omega (Pty) Ltd
Ms	Lee-Anne	Proudfoot	AGES Omega (Pty) Ltd
Mr	Preddy	Mothopeng	BLACK IT Forum
Dr	Avela	Majavu	Black Women in Science Fellow
Ms	Pumza	Makaula	Cape Peninsula University of Technology
Dr	Thandeka	Mthethwa	Cape Peninsula University of Technology
Dr	Justin	Yarrow	CodeMakers
Mr	Chris	Campbell	Consulting Engineers South Africa
Mr	Saddam	Matanzima	Council for Scientific & Industrial Research
Ms	Nokuthula	Zama	Council for Scientific & Industrial Research
Ms	Ramola	Chauhan	Department of Agriculture Land Reform and Rural Development
Ms	Ria	Wentzel	Department of Agriculture, Land Reform and Rural Development
Ms	Difela Barbara	Kalembo	Department of Water and Sanitation
Dr	Suresh Babu Naidu	Krishna	Durban University of Technology
Miss	Sandra	Carminati	Ecopath
Mr	James	Brown	Edifice Conseil
Mr	Ada	Dienga	Engineering Council of South Africa
Dr	Xolani	Nocanda	Ethekwini Municipality
Mr	Parthy	Chetty	Expo For Young Scientists
Ms	Thenjiwe	Sithole	Government
Ms	Palesa	Mofolo	Innovolution Edu Programmes
Mrs	Aisha Pearl	Mayekiso	Iziko Museums of South Africa
Ms	Zuki	Mashigo	JET Education Services
Miss	Molie	Moonyane	Johannesburg City Parks and Zoo (JCPZ)
Ms	Sanari Chalin	Malele	Limpopo Department of Agriculture and Rural Development
Dr	Dimakatso	Masindeni-Ndou	Limpopo Department of Agriculture and Rural Development
Mr	Kuda VJ	Murombedzi	Livingstone Kolobeng College
Dr	Hangwi	Akinwekomi	Magalies Water Board
Dr	Nkululeko E.	Damoyi	Mangosuthu University of Technology
Miss	Rirhandzu	Shingange	Maruleng Department of Agriculture and Rural Development
Mr	Shepherd	Chigogo	Maths Centre Incorporating Sciences

Title	Name	Surname	Organisation
Mrs	Mmamogo	Dikgale	Maths Centre Incorporating Sciences
Ms	Sharanjeet	Shan	Maths Centre Incorporating Sciences
Mr	Mxolisi	Lindie	MNL Business Solutions
Mr	Sibulele	Magini	Molo Mhlaba School
Mrs	Mamohlomi	Mtshisi	MSM Solutions
Mr	Xolani Mathews	Shange	National Skills Fund
Mrs	Nompumelelo	Moshoeshoe	Ndalo Enhle
Miss	Matshepo	Makitla	Ndlovu Care Group
Miss	Menzi	Penniston	Ndlovu Care Group
Miss	Owami	Thela	Ndlovu Care Group
Prof	Helen	Drummond	North-West University
Prof	Nnenesi	Kgabi	North-West University
Dr	Gerda	Botha	Private
	Sibusiso	Matshika	Private
Dr	Sarah	Motshekga	Private
Miss	Karabo	Padi	Private
Dr	Mmboneni	Tshivhase	Private
Mr	John	April	Quality Council for Trades and Occupations
Mr	Obby	Masia	Rand Water
Mrs	Sybil	Otterstrom	Romele Publication
Mr	Gordon	Branston	SDG Network Scotland
Dr	Sechene Stanley	Gololo	Sefako Makgatho Health Sciences University
Dr	Ramokone Lisbeth	Lebelo	Sefako Makgatho Health Sciences University
Mrs	Zanele Faith	Ramashala	Sefako Makgatho Health Sciences University
Ms	Florence	Seseng	Sefako Makgatho Health Sciences University
Dr	Lindi	Zikalala-Mabope	Sefako Makgatho Health Sciences University (SMU)
Ms	Mapule	Kgwale	Sibanye Still Water
Mr	Johan	Maartens	Society For Automation Instrumentation Measurement & Control
Miss	Abongile	Ndamase	South African Health Product Regulatory Authority
Ms	Pamela	Harirari	South African Health Products Regulatory Authority
Mr	Sylvester Curtis	Johnson	South African Health Products Regulatory Authority
Mr	Wayne	Muller	South African Health Products Regulatory Authority
Ms	Itumeleng	Makgato	South African Police Services
Mr	Jacques	Faure	Southern African Institute for Industrial Engineering
Mr	Bulelani	Mqolweni	Stellenbosch University
Dr	Christine	Steenkamp	Stellenbosch University
Ms	Roshni	Gajjar	StratAstute Consulting

Title	Name	Surname	Organisation
Miss	Candice	Nightingale	Sumitomo Corp. Africa
Ms	Tendesai	Chinamasa	The Independent Institute of Education
Ms	Nola	Payne	The Independent Institute of Education
Miss	Melida	Mabogoane	Tshwane University of Technology
Prof	Collet	Dandara	University of Cape Town
Ms	Mapula	Hlokwe	University of Limpopo
Prof	Mapotso	Kena	University of Limpopo
Prof	Wilmien	Luus-Powell	University of Limpopo
Prof	Richard	Mampa	University of Limpopo
Prof	Tshifhiwa	Mandiwana-Neudani	University of Limpopo
Mrs	Mekidela	Belay	University of Pretoria
Mr	Abdul Razak	Esakjee	University of Pretoria
Mr	Moloko	Malahlela	University of Pretoria
Prof	Ntebogeng	Mokgalaka-Fleischmann	University of Pretoria
Mr	Tedson	Nkoana	University of Pretoria
Dr	Thobela	Nkukwana	University of Pretoria
Prof	Nthabiseng	Ogude	University of Pretoria
Dr	Anicia	Maoela	University of South Africa
Prof	Samuel	Oyoo	University of South Africa
Dr	James	Ayuk	University of the Western Cape
Prof	Selo	Ndlovu	University of the Witwatersrand
Dr	Rozwi	Magoba	Vaal University of Technology
	Unknown		
	Unknown		
	Unknown		
	Unknown		
	Unkown		
	Unkown		
Mrs	Janusha	Singh	Wanscan Consulting
Mr	Maimela	Modiba	Wits Reproductive Health and HIV Institute
SPEAKERS			
Dr	Andrew	Paterson	JET Education Services
Mr	Bez	Sangari	Sangari South Africa
Mrs	Ellie	Olivier	South African Mathematics Foundation
Miss	Matshidiso	Morabi	STEAM For Kids Education
Ms	Kathryn	Kure	STEAM Foundation NPC
Dr	Kgadi	Mathabathe	University of Pretoria
Prof	Ian	Moll	University of the Witwatersrand
Dr	Derek	Fish	Unizulu Science Centre

Title	Name	Surname	Organisation
Dr	Nnditshedzeni Eric	Maluta	Vuwani Science Resource Centre
STAFF and SERVICE PROVIDERS			
Ms	Tamsin	Oxford	Coffee Content
Ms	Wilna	Eksteen	NSTF
Ms	Kelebogile	Galeboe	NSTF
Ms	Siyabonga	Jonga	NSTF
Mr	Barnard	Manne	NSTF
Ms	Seipati	Moleleki	NSTF
Mr	Matome	Mphela	NSTF
Ms	Itumeleng	Ndlovu	NSTF
Ms	Jansie	Niehaus	NSTF
Ms	Nonsikelelo	Nkwanyama	NSTF
Ms	Kgaugelo	Pule	NSTF-STEMulator
Mr	Richard	Gundersen	STEMulator
Mrs	Heather	Erasmus	Write Connection