“WE ARE TRYING TO TEACH THEM LIFE THINGS”: INSIGHTS FROM A UNIVERSITY-SCHOOLS COLLABORATIVE ENGAGEMENT PROJECT TO ENHANCE STEM TEACHING CAPACITIES AT SECONDARY SCHOOLS

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ABSTRACT

The state of school education in South Africa, especially in Science, Technology, Engineering and Mathematics (STEM) subjects, is commonly acknowledged as a great concern, to the extent that it has been called a national crisis (Grayson, 2009:7). This causes a long-term pipeline problem, or “articulation gap” (Case, Marshall & Grayson. 2013:1), in the tertiary education sector and in STEM-related job markets. There are consistently declining numbers of learners who choose subjects like Mathematics and Physical Sciences at school, which removes them from the pool of learners who could potentially qualify in these fields at post-school and tertiary level and who are therefore also lost to STEM careers. This article reports on a small multistakeholder university engagement project conducted between 2015 and 2020 at nine schools in one province of SA by the Engineering Faculty of a local university. A variety of STEM-related interventions aimed to upgrade facilities and equipment, supply resources necessary for the training of learners in the sciences and technologies and raise awareness of engineering careers among learners and teachers. This qualitative post-implementation research project used interviews to gather information regarding the perceptions of project collaborators (school educators, principals and university staff) about the university’s interventions to enhance STEM teaching at participating secondary schools. The findings were collated into ten themes that speak of benefits for learners and educators, improvements for schools and the university’s role regarding social responsibility. The knowledge gained through these interventions can be extended to and applied by other STEM training sectors and programmes, both public and private.

Keywords: higher education, STEM, South Africa, secondary schools, engineering, university engagement

INTRODUCTION

The state of school education in South Africa (SA), especially in Science, Technology, Engineering and Mathematics (STEM) subjects, is commonly acknowledged as a great concern, to the extent that it has been called a national crisis (Grayson, 2009:7). This causes a long-term pipeline problem, or "articulation gap" (Case, et al, 2013:1), in the tertiary education sector and in STEM-related job markets. There are consistently declining numbers of learners who choose subjects like Mathematics and Physical Sciences at school, which remove them from the pool of learners who could potentially qualify in these fields at post-school and tertiary level and who are therefore also lost to STEM careers. More adequate STEM education and training along the whole educational and employment pipeline, but especially in secondary schools, is often posited as a possible means to address at least some of these problems (NSTF, 2018).

This article reports on a small multistakeholder university engagement project conducted between 2015 and 2020 at nine schools in one province of SA. The Engineering Faculty of a local university implemented a variety of STEM-related interventions at nine participating schools, aimed at upgrading facilities and equipment, supplying resources necessary for the training of learners in the sciences and technologies generally required for engineering study, and raising awareness of engineering careers among learners and teachers. A qualitative research approach was followed to gather data form project collaborators by means of semi-structured interviews. The guiding question, which informed this research project, was "What are the perceptions of project collaborators (school educators, principals and university staff) about the university's interventions to enhance STEM teaching at participating secondary schools?". Using thematic analysis, this article presents a summary of the responses to this question and extrapolates from it observations and recommendations for future interventions of this kind. The findings of the study, collated into themes, indicated that university-led multi-partner engagement projects like this can be of great benefit to all concerned. This project was valued by participants for several reasons: it provided opportunities for learners to better understand and prepare for assessments, post-school further study or employment; it motivated learners towards improved learning and performance at school; it promoted a sense of awareness of health and safety, which is specifically relevant to STEM disciplines and jobs, and aided schools in meeting these requirements in class rooms and laboratories; it improved the profile and outputs of participating schools; it facilitated continued educator development and responsibility, which leads to improved teaching practices; and it provided or supplemented resources not available at schools, which facilitates better teaching of prescribed curricula. Lastly, it provided the university, its staff members and students with opportunities to get involved in a practical, socially relevant and responsive way in activities beyond the proverbial ivory tower.

The knowledge described here, gained through this project and its interventions, can be extended to and applied by other STEM training sectors and programmes, both public and private. Valuable insights from the participants can serve to inform planning for future projects like this, both at universities and across the post-school education spectrum, to arrest the problems in the STEM education pipeline in South Africa. This may help to undercut the severe youth unemployment rate in SA, could contribute to easing the expectations of and burden on already over-subscribed universities with far too high drop-out and failure rates, and may also incentivise innovation and small business endeavours among skilled youth.

LITERATURE REVIEW

The last Trends in International Mathematics and Science Study (TIMSS) results, for 2019, showed that SA learners "consistently scored in the bottom three countries" for a range of the related tests, with only 41 per cent of grade eight learners demonstrating basic mathematical knowledge and 36 per cent basic science knowledge (Businesstech.co.za, 2020; Mullis, et al, 2019). At university level the graduation rate for students who do enrol in STEM-related courses is as low as 20 per cent (NSTF, 2018). Graduation rates at Technical Vocational Education and Training (TVET) colleges are also dismal, with Pienaar, Venter, Govender. (2015:13, 14) citing as little as 2 per cent as the general throughput rate, with particularly low certification rates for Engineering programmes.

This is especially troubling in a developing country where STEM knowledge and skills are seen as a "gateway to economic development" (Chibale, 2022), yet many STEM jobs are earmarked as "scarce skills", as defined by the National List of Occupations in High Demand (Government of SA, 2020) and the Immigration Critical Skills List (Government of SA, 2022a). Large numbers of these "scarce" skilled workers often leave SA for more industrialised countries with better career opportunities. This while figures of higher than 30 per cent have consistently been cited as SA's unemployment rate, in particular for youth and post-school unemployment. Yet the SA National Development Plan (NDP) (Government of SA, 2013) states that, "quality education encourages technology shifts and innovation that are necessary to solve present-day challenges … society's ability to solve problems, develop competitively, eliminate poverty and reduce inequality is severely hampered without them" (Government of

SA, 2013:262).

Subsequent to the SA government's commitment a decade ago to its NDP vision for 2030, many initiatives and interventions have been introduced to address these problems. Yet, in his 2022 address at the launch of the SA Science, Technology and Innovation Indicators Report, the Minister of HE, Science and Innovation, Dr Blade Nzimande, noted that unemployment in SA was 35 per cent in the first months of 2022, "with black women and youth bearing most of the brunt", and that 24 per cent of South Africans live in extreme poverty. He also noted that SA's lack of skills is still a major and continuously increasing problem, with the country's skills rating ranking in the 84th place out of 158 countries and an innovation performance level that is behind other middle-income countries (meaning much is invested into innovation, but with comparatively few outputs) (Government of SA, 2022b). Much seems to be expected in SA of industry to support the educational system. However, this is an unrealistic expectation, especially in a country that is under-performing on many industrial levels and also amid the challenges of global pressures. Job-losses and cut-backs are a daily reality in industry, so looking toward industry as a panacea to salvage education must be tempered with a more realistic approach to the hugely complex educational and labour problems of a country like SA.

In 2022, Basic Education Minister, Angie Motshekga, announced changes to SA school curricula, including expansion to include 38 new subjects, many of them STEM-based, across three streams (academic, technical and vocational) (Government of SA, 2022c). This will align with the envisioned General Educational Certificate (GEC) that will be granted to learners at the end of grade nine. This may help to address the stigma associated with vocational training. SA has an extensive system of TVET colleges that aim to train for human capital and capacity development in vocational and occupational spaces where many of the scarce skills needs are situated. Yet TVET colleges are under-supported and under-valued. Only 31 per cent of all SA students were enrolled at TVET colleges in 2016 (Government of SA, 2018:7) and TVET streams of post-school education are commonly viewed as a lower quality or status than what is provided by universities, when, in fact, the different types of institutions provide training on an articulated and integrated post-school education continuum. Speaking about the new GEC, Seliki Tlhabane, the Department of Basic Education's (DBE) Chief Director for Mathematics and Science, noted, "children who are going into the TVET space [are often viewed by] society … as children who failed academically. We want to change this perception that TVET colleges and technical high schools are for children who are not intelligent" (Molele, 2022).

Improved STEM education in schools is therefore specifically relevant for learners from technical and special needs schools, who may progress into the job market straight from school, or after leaving school may join a TVET college for further occupational and vocational training. These learners may be the exact fit for the level of training that has largely disappeared from much of the SA education scene, namely the "scarce skills" artisan and apprenticeship niche, which is a highly sought after and much depleted entry level employment stratum in the job market. One specific articulation problem emerged in special needs schools, where in recent years the technical curriculum changed from three to four years to accommodate the previous age discrepancy, which meant that learners could exit school as young as fourteen and because of their minority age would be unable to legally be employed. The now longer four-year curriculum means that they are more likely to be at a legally employable age when they exist school.

Since the STEM problem intensifies "down the pipeline" in post-school and tertiary educational institutions, many have involved themselves in collaborative initiatives with government, industry, the private sector and schools to address the existing problems, especially in non-fee paying, disadvantaged, rural and township schools, where the problems are often greatest. Universities specifically become a reservoir for problems at a post-school level when students are insufficiently prepared for university study in STEM-related fields and are therefore either unable to gain entry into these courses, possibly have to first enrol in bridging courses (that not only add years to their formal study programme, but also increase the cost of their studies and delay their entry into the job market), or, if they do indeed gain entry into these courses, are often unable to cope and either drop out or fail to progress.

Most universities require at least a minimum of 50 per cent in Mathematics and Physical Science (so-called gateway subjects) at grade twelve level for entry into STEM-related courses, while many courses may require far more than this as entry requirement. Yet, the pass rate that will earn a grade twelve learner their National Senior Certificate (NSC) is 30 per cent. Often more than 80 per cent in both these subjects is required for university study towards degrees in Medicine, Engineering, Accounting, Law and Computer Sciences. These high entry requirements may exclude under-performing learners who may have an interest in, or even the potential for, these careers, but whose NSC performance may be impacted by their reduced exposure to and lack of support in STEM subjects at secondary school. The total number of learners who choose to pursue STEM subjects up to NSC level decreases annually, therefore fewer potential entrants to university STEM courses are produced, and learners who fare poorly in these subjects often leave school early (Van Gend, 2022). The national pass rate for Mathematics was 51 per cent in 2016, 52 per cent in 2017, peaking at 58 per cent in 2018, and declining again to 55 per cent in 2019 and 54 per cent in 2020, during the COVID-19 pandemic (Matos, 2021). Physical Science followed a similar trajectory: 62 per cent in 2016, 65 per cent in 2017, peaking in 2018 and 2019 at 74 per cent and 75.5 per cent, respectively, and then declining again, at the height of the pandemic in 2020, to 66 per cent (Matos, 2021). The next couple of years will prove whether the upward trajectory of 2018 was an anomaly or may be a recoverable ongoing trend that was interrupted by the pandemic. The "lost generation" (UNICEF, 2020; Gill and Saavedra, 2022) of the pandemic years – with up to 200 lost days of schooling and a reported learning poverty rate of up to 70 per cent (Gill and Saavedra, 2022) – will now enter post-school or tertiary educational institutions.

The general pass rate problem in SA schools, universities and colleges has been a longstanding concern since the NSC qualification was introduced in 2008. NSC pass rates is a particular concern in the Eastern Cape Province of SA, where Nelson Mandela University – one of the partners in the project reported on here – is located, and from whence it attracts many of its students. The province consistently scores as one of the provinces with the lowest NSC success rates, with a general decline of 8,3 per cent in 2020 (68,1 per cent, with progressed learners) from 2019 (Government of SA, 2021). In Gqeberha (previously Port Elizabeth), the largest city in the province, the number of learners who wrote Mathematics or Physical Science examinations as NSC subjects peaked in 2011, with 4917 NSC candidates in Mathematics and 3728 in Physical Science, and then showed a steady decline to 2828 in Mathematics and 2091 in Physical Science in 2021. Performance in the NSC examinations by those who did choose these subjects also declined, with 747 learners achieving 50 per cent or more for Physical Science in 2019, compared to 1142 in 2011 (Van Gend, 2022).

A few probable causes for this decline in both interest and performance in STEM subjects at schools can be posited (Van Gend, 2022). First, because students perform poorly in these subjects in grade nine, they are unable to continue with them in higher grades. Second, educators of STEM-related subjects are often not qualified or sufficiently trained to teach these subjects at higher levels and therefore fail to effectively assist learners who may have the potential to progress and perform well. Third, many schools, especially non-fee paying, underprivileged, rural and township schools, lack the equipment, resources and infrastructure to teach these subjects. There is often also little or no upkeep of equipment and infrastructure and even large-scale vandalism, burglary and theft at these schools. Vernon Esau's Master's thesis (2007) investigated this specific problem at schools in the city where these interventions were implemented. He concludes his study by stating that,

> "School vandalism is a serious threat to the establishment of a culture of learning, democracy and economic progress … there is a danger that some learners may develop the perception that vandalism is an acceptable way of expressing frustration, taking revenge or showing anger, lending excitement to a dull existence or drawing attention to a specific issue. Linked to this, teachers, learners and members of the community may develop a laissez-faire attitude towards vandalism, for fear that vindictive learners may vandalise their personal or school property and

that no action will be taken and the problem escalate further."

Fourth, there seems to be a decline in students who engage in homework outside of school hours and away from school premises. There could be a variety of factors responsible for this, for example, a general culture of poor study habits; a lack of support at home; a home environment that does not facilitate dedicated homework conditions (for example, no electricity, electronic connectivity, privacy, parental involvement or adequate supervision); and a lack of enthusiasm for learning among both educators and learners, especially if hands-on and active experimentation does not happen in classrooms and therefore cannot form a basis for conceptual follow-up work at home. The problems are well-known, widely researched and well-reported. Yet devising and implementing effective and efficient solutions at a sufficiently rapid speed to arrest the problems is where the challenge lies.

PROJECT DESCRIPTION

Set against this background, this article reports on a small multi-stakeholder university engagement project conducted between 2015 and 2020 at nine schools in the Eastern Cape Province of SA. Participating schools were identified by the university in collaboration with the DBE. The schools all present technical subjects and all have between 600 and 700 learners, with approximately 45 to 50 learners per class and 60 learners to be accommodated in technical workshops, usually occupied on a rotation basis, since a standard workshop accommodates only about 15 learners at a time. Participating schools included two senior secondary schools, four comprehensive schools, one special needs high school and two technical high schools.

The Engineering Faculty of Nelson Mandela University implemented a variety of STEM-related interventions at the participating schools, aimed at upgrading facilities and equipment, supplying resources necessary for the training of learners in the sciences and technologies generally required for engineering study, and raising awareness of engineering careers among learners and teachers. Initiatives included outfitting electrical, drawing and welding laboratories, installing water tanks and renewable energy resources at schools, building and providing schools with STEM science kits, custom designing and presenting training for teachers to use specialist technologies and equipment, donating teaching equipment like data projectors, and presenting STEM career awareness events at schools.

Interventions relating to electrical laboratories included full laboratory refurbishments (including the installation of necessary tools and cupboards), the design and installation of programmable logic controller (PLC) stations and the training of staff to use the stations to train learners. Drawing laboratory interventions included the making and installation of the necessary infrastructure, including drawing tables where students can sit down to do technical drawings. Where possible learners themselves were guided in the construction of their own tables and instead of using outside contractors for tasks like painting and building, the university used qualified members of the school community for these tasks. A local South African welding industry leader donated hardware and consumables for the welding laboratory interventions. The university physically prepared the venues, installed all hardware to appropriate safety specifications, for example the putting up of welding curtains, painting windows black and installing gas cylinders. The university also sourced materials for and constructed outside open mesh cages for gas cylinders, constructed and installed burglar bars and ensured that there were electrical outlets wherever necessary. Rainwater tanks and pumps were installed at schools to facilitate the pumping of water into ablution facilities and solar panels were installed to optimise energy provision.

The STEM science kits provided to schools comprised of all the necessary equipment and consumables to perform all experiments included in the grade ten Technical Science Curriculum Assessment Policy Statements (CAPS) curriculum, as well as specially developed learner and educator guides. Educator training to use the kits was also provided to educators from the participating schools. Kits like these are costly and need to be updated annually to ensure continued effective use in classrooms with new groups of learners. This needs further attention and continued funding. For example, a typical grade ten Technical Science class consists of about 40 learners. It will be ideal if each educator could have at least eight kits so that all the learners in the class can perform and actively participate in experimentation at the same time, if groups of 5 learners work together, as opposed to just having experiments demonstrated to them by the educator. Kits for other grades would need to consist of curriculum-specific content and would require the compilation of unique grade-specific learner and educator guides.

A total of 2771 learners were reached through STEM career awareness workshops and road shows, including in far-flung rural areas of the province. Some of these events were conducted in collaboration with a local TVET college. Learners were introduced to both college and university study programmes in engineering and possible careers that could be entered with engineering qualifications. Learners were also informed about latest technology developments, research projects that were being undertaken at the university, and how these articulated with potential career pathways. Some of the university's engineering vehicle prototypes were taken on the road shows for viewing and hands-on experimentation by learners, for example, a solar powered vehicle, an eco-car and the university's Formula Student Race vehicle, with which they competed in races.

Sixty-seven technical secondary school educators from forty-eight schools in the province attended a bespoke, custom designed by the university, fit-for-purpose five-day AutoCAD training workshop that catered for persons with no prior experience of the software. This workshop introduced attendees to the basic concepts of AutoCAD, through to the full working drawings package for Engineering Graphics Design (EGD). Software was made available to them via an online site from which they could access it when they returned to their schools. The university also facilitated contact between the participating schools and a supplier of AutoCAD, who committed to supplying the schools with free copies of the software for use by learners. This is a significant achievement in multistakeholder collaboration, since the software is extremely costly and unlikely to be accessible to schools in any other way. Six educators from participating schools, including a DBE representative, also received welding training in Johannesburg from a South African industrial company that is a sub-Saharan market leader specialising in gasses and welding equipment.

METHODOLOGY

Though the interventions in schools were implemented between 2015 and 2020, before the global COVID-19 pandemic of 2020 to 2022, the post-implementation qualitative research was conducted during the pandemic years. Data gathering could therefore only be conducted using digital platforms as researchers could not access school premises or physically meet with interview respondents. Semi-structured interviews were conducted remotely with participants from schools and the university who were involved with the execution of the initiatives. Convenience sampling was used – only nine schools were involved in the project and all nine were invited to participate in the interviews, but only 3 schools volunteered to do so. This was due to the time pressures and constraints they experienced during the interview period, which was just as schools changed back from remote teaching to managing children on school premises again. Load-shedding and interrupted access to electricity, connectivity and access to data and virtual platforms also presented problems.

In-depth interviews were conducted in English with three school principals (two of whom are also STEM educators), two STEM school educators, four university staff members, as well as the project leader and project manager. Information was gathered about their perceptions of the university's interventions to enhance STEM teaching at participating secondary schools. The interviews were recorded and transcribed. Using thematic analysis (Braun and Clarke, 2006) broad themes were extrapolated from the interviews. Ethical clearance for the research was obtained from the university and the provincial office of the DBE. Participation was voluntary and participants were informed of the purpose of the interviews and their participant rights (including anonymity and confidentiality) and signed informed consent forms before interviews commenced.

Limitations of the study are that data were collected during a specific time period (of great upheaval) and from a small sample of schools in one province, with specific common problems relating to STEM teaching, so data may not necessarily be generalisable to all schools in SA. Another limitation is that perceptions of learners and their parents/guardians were not included. The pandemic, lockdown and remote working processes made it logistically impossible to locate and include them as study participants. Tracing learners after matriculation is nearly impossible and would require infrastructure and post-school records not available at and from schools. It is advisable that future initiatives like this should from the outset include, in their project design, methods for extracting longitudinal data, such as marks and grade data, from schools, for comparison from year to year, before and after the introduction of the initiatives. Quantitative and qualitative data combined in such a mixed method study would serve to further enrich the findings and conclusions about interventions like this. As this was not part of the original project design at the outset, there would have been ethical and confidentiality concerns around retrieving and interpreting such data retrospectively. A major challenge experienced during this study, which could not have been foreseen at the planning stages, was the COVID-19 pandemic. The national lockdown rendered all normal research activities related to this project impossible, while universities and schools alike went into crisis adjustments to accommodate remote on-line teaching. This also impacted on the amount of time that it took to obtain ethical approval and clearance for the study from the university and the DBE.

FINDINGS AND DISCUSSION

Ten themes were identified from the data gathered in interviews, which are discussed here. The themes are: facilitating opportunities for learners; preparation for assessments and post-school employment; improved motivation to learn and perform at school; health and safety; improved profile and outputs of schools; perceptions about reliability and responsibility of external benefactors; training and accountability of educators; effective school leadership; the necessity for adequate resources, and the university's social responsibility.

Facilitating opportunities for learners

The educator-participants from schools were asked about their greatest teaching joys and their feedback invariably revolved around the facilitation of change and opportunities in the lives of learners. One educator, from a special needs technical school, said,

> "we work with rough and difficult kids … they often have nothing to live for … they go home

> and there's nothing for them there, until they come to school and we start teaching them a skill, a thing that can maybe in future be to their advantage and raise them out of their circumstances … [to get them] to understand that we are not just here to teach them school things, we are trying to teach them life things … that is my greatest challenge and my greatest achievement … if you can break through to a kid's thought process and you can make them understand that you are not actually working against them, that you're working for them and you're fighting for them, for their future …"

All university participants commented on the way in which university engagement initiatives like this prepare learners for university, further study and the working world. One noted, "[initiatives like this] bridge the gap … by having universities [involved] in schools like this, you can hopefully better prepare the pupils in high school for varsity".

Though there is a specific niche market for these kinds of initiatives among technically focused schools, academic schools can also benefit, because universities usually attract students in STEM disciplines, like engineering, from academic schools. One university participant said, "I would really like to see academic schools teach industrial type programmes, even if it's not part of their curriculum … I think adding some equipment to those schools, even at a reduced capacity, would inspire future engineers and programmers. … Giving such exposure to academic schools would really benefit the university from an engineering degree perspective".

Preparation for assessments and for post-school employment

When asked about the benefits of the new facilities installed at their schools by the university, educators reported that all learners can now participate in class and can complete their practical work more effectively ("then we don't have people sitting and waiting for the machine to open up so they can get a turn…"), which improves exam marks. One educator noted that learners with practical experience, "[have] got an advantage above other learners just leaving school with no practical experience …". One principal pleaded for some form of accreditation for learners, "so they have something when they leave school" by means of which they can prove their acquired skills and enter the working world as an apprentice or artisan-trainee after school. Educators noted that government provided no support to special needs schools with the implementation of the recently extended four-year technical curriculum: "there's no text books, there's no guidance … we are working out of our own notes, which takes hours and days of work for the teachers to do".

The consensus among university staff members was that "the schooling system lacks the tools and skills to equip future entrepreneurs and inspire future technicians and engineers". University staff members commented that initiatives like this prepare leaners for the world beyond a school. One said, "it opens kids' minds as to what's really possible and what is done in the real industry". They also recalled their own school experiences; one said, "if I just think back [to when I was at school], if I had the access they've got now … it's incredible … I wish we had this type of equipment at school and [were] exposed to industrial training equipment at this level at school".

Improved motivation to learn and perform at school

Educators mentioned that the motivation among their learners are notably higher with access to the resources these interventions supplied and that "it feeds their curiosity to learn". One said, "if you practice more, then you will get better at something and being able to do that with the new equipment [meant that] we had better and more positive responses in terms of our learners' skills, [because] they spent more time on the machines". Another noted that, "we saw a positive reaction [among learners] … they were very keen to try [the new equipment] out … a healthy competition started between the learners, which gave them hope". One said, "I think it inspires kids to design, create and perhaps even motivates [them] to do well at school and [gives them] a vision of what they can do after school".

Health and safety

As part of this initiative the university provided schools with Personal Protective Equipment (PPE), which one educator said, "helped enormously … we are all about safety in the welding workshop, there are many dangers". With the donated equipment they could practically demonstrate the theoretical work in the textbook to their learners, which changed the nature of their teaching methodology and the learners' engagement with, interest in and motivation for their schoolwork. When asked about the upkeep of facilities, all educators noted that they were managing to achieve that effectively. One said, "we don't mess around with that because if an accident happens in my class [Welding] it's gonna be big, so if there's something wrong, we get it fixed right away and we get proper help and support from school [management]". But procuring further infrastructural support seems to be a common challenge, because of inadequate funding from the DBE and from parents/guardians.

Improved profile and outputs of participating schools

The general consensus among participating educators was that they were glad to have been a part of this collaboration initiative and to have benefitted from it, both personally and institutionally on behalf of their school. One principal said he was very proud of the results at his school and that he often shows visitors the new facilities. Another noted anecdotally that enrolments visibly increased as the availability of the new facilities became known. He cited the improvement in grades at his school to show the success of these initiatives. He said that the grade twelve pass rate was as high as 87 per cent in 2021, 94 per cent in 2020 and 97 per cent 2019 and subject results improved 80 per cent since 2018 when the school started collaborating with the university.

Perceptions about reliability and responsibility of external benefactors

There seems to be a general lack of understanding at schools-level about the roles and responsibilities of various partners in collaboration initiatives. For example, schools tend to view government, universities, TVET colleges and industry as indistinct and interchangeable. The positive experience of multi-stakeholder collaboration projects is not necessarily a norm. One principal said schools are often initially suspicious of external benefactors. He said, "we knew years of stuff like this … people say they wanna come and help you and they wanna do something for the learners. And what? Then what? The first idea you get is here comes a lot of meetings and talking and no action and no delivering". However, he noted his experience with the department of the university that led this specific initiative was "exactly the opposite … [they] delivered … we had our meetings and then bang [they] delivered …". He called it "a big success story".

Training and accountability of educators

About their own development as part of this project's initiatives the participating educators all said they were hugely appreciative of the training provided by the university and industry as part of these initiatives and they consistently asked for more of the same. One of the participants noted that "the average SA educator is a creature that is very much under pressure". Great pressure regarding technology in particular is placed on STEM educators, many of whom were not trained to use the current and constantly changing technology. One educator noted that, "during my studies towards my profession there was more theory than practical, then continuous professional development enhanced my confidence and closed gaps that I had after I started working".

The university staff members noted that they observed that the educators often "have very limited knowledge … the practicals down at the school is very limited and mostly taught on theory level". They noted that they generally found educators very keen to get involved in the projects, but that "some teachers had to work a bit harder to grasp the material, maybe, being out of touch with industry". This speaks to a specific disjuncture between school learning and university study. For example, IT courses taught in schools are often presented in the style of business-orientated programming, rather than design-orientated programming, which is needed in engineering-based courses and later when working in industry. So when learners are accepted for university courses in engineering disciplines, based on their matric results in STEM subjects, they are often not familiar with the IT programmes used at university-level. Continued training in the latest technologies and teaching practices can help to close this gap and can result in more motivated and skilled teachers.

Another university participant said, "sometimes the teachers think that doing more practical activities will waste time, while they could be teaching, instead of actually using the equipment as a teaching tool" and said that a culture of practical activity should be encouraged as early as possible, so it becomes embedded with learners and educators alike at the earliest possible grade level and age group. One university staff member had more than a decade of experience working with university-led STEM projects in schools. She noted that,

> "from experience over years [I know] that educators do not do practical activities at schools for two reasons, three reasons, actually. Number one, they are very set in their ways about how they teach; number two is they do not have the equipment at their disposal; and number three is they don't have any experience in presenting and facilitating practical activities, so there is a huge lack of confidence. … Schools will always take whatever you want to give them, but then the second phase of that is [that] unless they feel empowered to use the equipment, it will just lie in the storeroom. So the teacher training aspect is incredibly valuable – even then only 50 per cent of them will take it up because there's a huge resistance to change [especially] with IT, it's very hard for them to adapt and take this on board."

Another university staff member noted that there is "a lot of negative information coming from news and media … about teachers and schools. But there's still a lot of passionate teachers in very poor environments and given the right tools they excel and they're quite enthusiastic too".

Effective school leadership

The most consistent message that emerged was that effective school leadership is essential in ensuring continued training and accountability of educators as well as the maintenance and upkeep of equipment and resources. One university participant noted that "the attitude of the individual teacher really is what makes or breaks the school's involvement … also the principal, they also have to get involved and … make sure that the teachers are actually doing what they are supposed to be doing". Another confirmed this by saying, "it depends on the type of teacher who is at the school … some schools embrace it and take it on and run with it … it depends on how well-functioning the school is and then who the individual is that's in charge and to what extent that individual can inspire the other people to actually take this on board".

The necessity for adequate resources

When asked about their greatest challenges, educators invariably cited resource shortages as the biggest concern. They seem to feel this is largely responsible for the high failure and drop-out rates. They find this very demoralising. The technology available in schools, especially in technical-orientated schools, are often out-dated, by as much as two decades.

When asked to compare what they found at schools before they started the interventions to what was at the schools when these initiatives were completed, the university staff members noted, "they [schools] have a lot of space, but no equipment", "the equipment in schools were very outdated" and "we found an empty classroom and when we left there were two rows of back-to-back workstations kitted out with tools and equipment ready for them to start using it and learning and teaching".

About the benefit of the programme to schools, one university participant noted, "we definitely added something into the schools … it gives them a good platform and provides them with more opportunities than they had". One said, "it lifted the quality of the equipment in the classroom … the school now had practical stations that were at a professional industry training level … what you would expect going to any private training centre", while another noted that "I think [initiatives like these] make the job [of teachers] easier. Not that teaching is ever easy, but you can imagine how difficult it would be to, say, learn the alphabet for the first time without alphabet flash cards. The equipment we provided were the alphabet flash cards those teachers needed".

University's social responsibility

Collaborative engagement projects like these provide opportunities for vital broader skills training for university students and staff, not only in their specific disciplinary praxis, like engineering, but also in working as part of transversal and multi-stakeholder teams. It also lays a foundation for civic responsibility, which they may later carry into their working lives. University participants reported "a feeling of satisfaction" about being involved with initiatives such as these. One university staff member said, "completing a task or solving problems is what makes me happy … knowing that solution is now benefitting others just makes that feeling ten times better". Another said, "it's something that I enjoy being a part of and probably would have offered my time for free if I wasn't working for the university".

One university staff member summed up the value of multi-stakeholder collaborative engagement projects and initiatives like this by saying that "we've got a duty, I think, as university, to our environment to give back to the community. … I do think everybody has a lot to gain from something like this. And I don't think it's a "nice to have", I think it is really a necessity and a requirement to have". He explained further that,

> "we put a lot of emphasis on the handshake between university and industry to make sure that we put the right level of engineers or technicians out into industry and essentially deliver on the

> product that industry wants – an employable person. And I think it's very important we do it the other way around as well because schools need to deliver the right product to be coming through to university. So you know you've got that continuity that you need all the stakeholders from grade eight all the way through to an employable person and it requires all the stakeholders in between to be talking to each other to achieve that."

One university staff member also advised for some caution and insight into the larger factors that schools contend with. She noted that "at first I thought I could convert everyone and I could motivate everyone and I could teach everyone and that everyone's got the potential to improve. But regardless of the child's cognitive ability, there are so many factors influencing the child's performance – socio-economic factors. So, at the end of the day I've learned to focus on the positive."

CONCLUSION

This article presented findings from a small qualitative research study about multi-partner university-school engagement. Valuable insights from the participants can serve to inform planning for future projects like this, both at universities and across the post-school education spectrum, to arrest the problems in the STEM education pipeline in South Africa. In order to achieve this it is essential that engagement, transfer and outreach projects such as these must be well-designed and well-managed, must operate from a basis of clearly defined goals and responsibilities and that funders, benefactors and project partners must be effective, efficient and accountable in the manner in which they implement and execute projects and follow through on initial expectations that are created and on promises and commitments that are made to schools.

Well-meant and aspirational intentions must be balanced with situational and contextual realities. Each prospective beneficiaries' context must be thoroughly assessed before deciding on the nature and extent of the intervention. The quality of school management; investment and involvement of staff; security of premises, infrastructure and equipment; long-term sustainability and longevity through upkeep and maintenance; and involvement of the broader community, should be taken into consideration when making assessments. The most important factor in the successful implementation of any intervention is careful and thorough selection processes: choosing functional schools where there will be uptake and support for the initiatives at all levels. This will go a long way to optimise not only the initial investment, but to also ensure sustainability and longevity.

A three-pronged approach is essential for projects like these: simultaneous human capital development, infrastructure development and financial investment. Of these, the highest priority must always be continued human capital development. To invest technology and equipment alone, and expect results, is foolhardy. If there is not sufficient human capital developed for the optimal utilisation and application of the equipment, technology and infrastructure, the initiative is doomed to fail. Large-scale recapitalization projects in schools are needed, especially at technical schools, but also in academic schools where more technical subjects should be presented with greater practical emphasis, to provide academically strong learners a strong basis in practical STEM knowledge, to improve their competitive edge when they enter universities.

Training opportunities for educators and professional development workshops during holidays are particularly pertinent needs. Educators need to be updated about the technology used at post-school level and in industry to optimally train learners for the STEM pipeline. More collaboration with government (for example via Services Sector Education and Training Authorities (SETAs)), industry and TVET colleges is needed to facilitate accredited artisan training programmes and learnerships and to address this gap in the training and labour market.

The loss of high-quality, dedicated and experienced educators from the schooling system is a concern. A generation of educators are aging-out of the schooling system, as they reach retirement age; others decide to leave the profession because of the frustrations associated with teaching in the difficult school context in so many SA schools. "Where is the new generation of technical educators?" is the question that should lead future interventions around STEM teaching in schools. There is a widening gap between the skills with which student educators at universities are equipped and the skills needed by STEM faculties in universities and by industry. The disconnect between what faculties of education teach education students and what is required of school leavers to enter STEM university courses, or jobs in industry, is likely the result of the gap that was left by the demise of colleges of education in SA two decades ago. If universities do not effectively prepare education students to teach high quality skills to learners at school, the cycle will continue and the excessive need for interventions by external stakeholders will only increase, while their effectiveness may not. It is therefore imperative that education faculties at universities engage much more extensively with STEM faculties and disciplines and with industry, to ensure that the curricula of education faculties, especially in STEM disciplines, are well-articulated and provide education students with the required skills to adequately prepare school learners.

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