A contact-based practical approach to STEM projects in South Africa[1,2]

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ABSTRACT

In South-Africa, there exists a shortage of technicians, technologists and engineers. This paper aims to document one approach that can be followed to entice young inspiring and intelligent learners from the secondary teaching institutions to enroll for engineering studies at a recognised university through Science, Technology, Engineering and Mathematics (STEM) -based projects. The Technolab at the University of Johannesburg is an entity that was started to promote the Engineering School of the University to secondary schools. The aim is to use exciting fun technology project challenges to entice younger learners to enroll for engineering studies at the University of Johannesburg. The technology project challenges are administered by the Technolab at the University of Johannesburg. In this paper, three of the main Technolab projects are discussed, including the difficulties experienced in terms of the logistics and difficulty level of the project. The primary contribution of this paper is the model adopted to host STEM-based projects in South Africa and the impact of this model that leads to increased participation. In 2016 and 2017 for the AfrikaBot competition, there were 45 and 56 participants respectively and 25 and 40 successful completions respectively. For the CO2 dragster challenge, from 2014 to 2017, the number of participants increased from 22 to 129. For the Weather Station challenge during 2014 and 2015, there were a total of 22 participating groups and 14 successful completions.

INTRODUCTION

The Technolab in the School of Electrical Engineering at the University of Johannesburg is an entity used to present Science, Technology, Engineering and Mathematics (STEM)-based projects to entice learners to enroll for Electrical Engineering studies. The current secondary education system has somewhat seen the need to incorporate some engineering work into their curriculum as an extension to physics, as a choice subject such as Electrical Technology, Electronics and Digital Electronics (Dept. of Basic Education, 2018a, *Grade 12 Exemplars Technical Subjects*). These subjects have had multiple titles but these subjects have been presented since 2008 (Dept. of Basic Education, 2018b, *National Senior Certificate (NSC)*

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2 The authors would like to thank the Technolab staff for availing their resources and time to host the STEM projects. The authors would like to thank the various secondary school educators, their learners and parents who availed their time to make these projects a success. The knowledge gained in how to approach and host STEM based projects in South Africa in a practical way is accredited in part to their efforts.

Examinations). However, not enough exposure is given to learners at secondary school level, which causes learners to be hesitant to enroll for engineering studies. Therefore, to entice learners to enroll for engineering studies, extensive use of contact-based support is used to enable learners to gain the necessary knowledge and skills to complete fun engineering technology projects successfully. In this paper a contact-based approach in hosting STEM-based projects is presented, which can greatly increase enrolment of students in engineering studies in South Africa. A thorough discussion on the logistics, advantages and difficulties is also presented.

LITERATURE STUDY

Engineering educational institutes in South Africa embrace learners that enroll for engineering studies based on their own interest in the engineering discipline. However, educational institutes also try other methods to entice learners to enroll for engineering studies. Active practical involvement in projects significantly improves learning when students build something meaningful (De Cristoforis, Pedre, Nitsche, Fisher, Pessacg & Di Pietro, 2013). Also, an effective STEM-based community outreach project must include the support of educators (Bruder & Wedeward, 2003).

Several models can be used to promote STEM education of which some examples are given in this paragraph. A mobile truck with engineering equipment is one way to bring the STEM project to the learner (Lovegrove, Batdorf, Corey, George, Pinkston, & White, 2017). Cyberlearning is another model that can be used to promote STEM education (August, Hammers, Murphy, Neyer, Gueye & Thames, 2016). Cyberlearning generally appeals to today's youth and uses modes of information management and social interaction that is almost second nature to the current generation of learners. Cyberlearning is defined as learning that is mediated by networked computing and communications technologies (Borgman, Abelson, Dirks, Johnson, Koedinger, Linn, Lynch, Oblinger, Pea, Salen, Smith & Szalay, 2008). The Internet has matured sufficiently to support sophisticated tools, content, and services thereby becoming a viable educational platform. E-Learning however, has many interpretations but also stands for learning by electronic means and can be further categorised into formal lessons, which are structured, and use informal means such as discussions or e-mails (Bhandari, 2003:1). E-Learning includes both types of learning that does not come directly from lecture notes, books or face-to-face with a teacher but rather through electronic means.

Students struggle mostly with adapting their already established collaborative strategies that are grounded in face-to-face learning, to an online learning environment where they felt their means of communication and expression were limited (Mehlenbacher, Autry & Kelly, 2015). Established collaborative strategies are paper-based and face-to-face methods whereas online learning strategies include Google Docs and online courses require computer and internet infrastructure. For this reason, we chose the face-to-face model of approaching our STEM-based projects.

Learners from underrepresented minorities often do not participate in extracurricular engineering activities because of a lack of non-technical teacher skills and non-continual exposure to STEM-based projects, which applies to both practical and online approaches (Cross, Hamner, Zito & Nourbakhsh, 2016; Nair, Huang, Jackson & Cox-Petersen, 2017; Doherty, 2016; Mehlenbacher, Autry & Kelly, 2015). It has been reported in literature through conducted surveys that interest in STEM education is currently lacking (Nair et al., 2017; Gaitan-Leon & Tafur, 2017). Government institutions through their established methods have determined that STEM outreach programmes do not extend broadly enough to inspire promising learners (Hurlburt & Voas, 2013). Government intuitions and other reliable private sector efforts, have determined that STEM education promotes the development of future engineers and for this reason the success of STEM programmes is of great importance (Nair et al., 2017; Gaitan-Leon et al., 2017; Lovegrove et al, 2017).

A good model to promote STEM-based education is to present contact-based workshops because learners are used to face-to-face learning methods (Andrijcic, Ingram & Siahmakoun, 2017; Gruenbacher, Nararajan, Pahwa, Scoglio, Lewis & Muguira, 2007; Tay, Lim & Chua, 2017). This model is costlier because of finances required for equipment, required face-to-face contact time and the remuneration of qualified educators.

RESEARCH METHODOLOGY

As this research was done on new STEM projects, a mixed mode research methodology is adopted. Mixed-mode research methodology consists of qualitative as well as quantitative research techniques (Petter & Gallivan, 2004). There are six types of mixed-mode research methodologies that can be used such as sequential explanatory, sequential exploratory, sequential transformative, concurrent triangulation, concurrent nested and concurrent transformative (Creswell, Plano Clark, Guttmann & Hanson, 2003). For this work, a sequential explanatory mixed-mode methodology was chosen since it combines perceptions as well as numerical data collected where the quantitative methodology was first employed and then the qualitative methodology. The benefits of using mixed-mode research is the potential strength that offsets weaknesses in quantitative and qualitative research methods, the ability to provide more and better evidence when studying a research problem, assistance in answering questions that cannot be answered by qualitative or quantitative methodologies alone, and encourages the use of multiple views when performing research (Choudhary & Jesiek, 2016). Regarding the qualitative methodology, an interpretivist research paradigm was chosen which enables one to analyse and offer a perspective of the situation under study and provide insights into the way in which individuals make sense of the situation (Maree 2011). In the explanation that follows, each project's qualitative and quantitative research methodology is discussed.

For all three STEM-based projects - Afrikabot, CO2 dragster challenge, Weather Station challenge - the actual project is first introduced to prospective learners in several ways ranging from road shows to meetings with parents and in-person presentations. The primary aim of the presentation phase is to gather information and feedback from prospective learners and parents to determine the amount of interest in each project. One of the primary factors in the decision to participate in a project is the cost and time needed of which the Weather station is the highest and the Co2 dragster is the lowest. No set way in terms of questioning and presentation was followed, as for each project the prospective learners' interest is different. The project is presented, costs and logistics are discussed and then through verbal as well as documented feedback, the amount of interest is determined.

On a continual interview basis, feedback mostly consisted of the answer to the following research questions. How well does a STEM project promote the interest in engineering where cost is not a concern? Did the STEM project capture the interest of the learners in such a way as to entice enrollment in engineering? In this way, through the perception of the researchers, the validity of the proposed approach and type of STEM project is determined. This makes up the qualitative approach in this research.

For the quantitative approach, some data analysis was performed and each one is discussed and justified accordingly. To measure success, analysis of the number of entrants at the start of the project, entrants in the actual event and the number of successful completions must to be documented accordingly. The only real way to measure the impact of STEM projects relating to engineering enrollment is to ask learners to willingly keep contact with us after completion.

For the Afrikabot competition apart from the assistance received from volunteering academics at the University, there were three staff members, namely a manager, a non-qualified technical employee and a secretary. However, three staff members alone cannot reach out to hundreds of students which resulted in poor record keeping, nor do they have enough technical expertise to ensure that projects are run successfully.

During the actual event, improved record keeping was carried out as learners had to fill in an entry form with their name, surname and grade. Additionally, they had to supply their school/college/university name and their team name. The team names are then entered into an excel spreadsheet with columns for three separate competition run attempt times. If a team fails to complete the challenge, it is then documented accordingly on the excel spreadsheet. In this way, the success of the challenge on the day is quantitatively measurable as documented in this paper.

For the CO_2 dragster challenge, the educators are first introduced to the challenge and then they have to motivate learners to participate. Also, some schools are evaluating the possibility of including this challenge as part of their curriculum. On the actual event day, the same procedure as with the AfrikaBot challenge is adopted with respect to the entry forms. For the CO2 dragster event, the name, surname, team name, grade and school name details are also recorded. The team names are then entered into an excel spreadsheet and the run times are recorded. It is also documented accordingly, if a team fails to complete a challenge.

For the Weather Station challenge, the initial data for the number of interested learners were obtained as the academics were in consultation with the school educators and had to issue the donated PLC units and power supplies. Since the Technolab staff were in continual communication with the educators, an accurate conversion rate from initial start to successful participants could be determined. On the actual event day, the name and surname, team name and school name details are also recorded. Again, if a team that participated on actual event day failed to finish the challenge, it was also documented.

The results are tabulated and presented later in this paper. The elements included in the table is the number of initial interested groups, the number of groups on the actual event day and the number of successfully completed groups.

SHORT OVERVIEW OF PROJECTS

This section outlines the three projects used to validate the model, namely the Weather Station, CO2 Dragster and AfrikaBot technology STEM-based projects. To outline the significance of this model, each project is discussed separately.

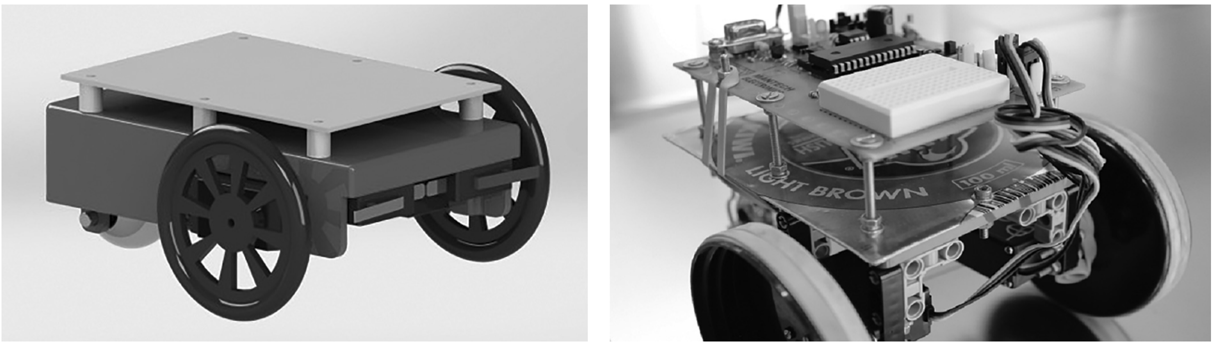
Robotics project: AfrikaBot

The detailed background of the AfrikaBot engineering project is provided in another publication (Nel, Ettershank & Venter, 2016). The AfrikaBot challenge requires learners to build a low-cost robot, which has to navigate through a set maze, where the non-electronic components are mostly made up of recyclable materials. The main aim is to promote STEM education in developing countries. By lowering the cost of equipment used, this enables preparing the youth in economically-marginalised countries for upcoming technical programmes.

By transferring enabling technology skills in a fun and engaging way, participants will rapidly build the confidence to pursue careers in STEM fields (Nel et al, 2016). However, one critical issue that is always present is funding. The AfrikaBot robot, although still cheap compared to other do-it-yourself robot kits, comes in at around R2000 (~155 USD) per kit. Several sources of funding from industry partners have been received for financially needy learners. Not only can the industry partners receive certain company exemptions, it is also in the management's interest that the learners succeed.

There are several key facets applicable to this robot. A detailed description is given in a recent publication (Nel et al, 2016). Both software and hardware are discussed thoroughly and for the purposes of this paper, this will not be repeated here. An example of such a robot is given in Figure 1.

Figure 1:
Example of a rendered AfrikaBot chassis and its implementation



In Figure 1, the chassis and an implemented example of an AfrikaBot is given. It can be clearly seen that the emphasis lies on recyclable material for the non-electronic part of the robot. Recyclable material greatly reduces costs which is a large factor in determining what kind of projects can be hosted as STEM projects at the Technolab.

The AfrikaBot project started in 2016 and will be continued in 2017. The Technolab staff hosted two events to give learners the opportunity to showcase their robots. The first opportunity was a first run semi-final event that was held at the University of Johannesburg. The second final event was held in conjunction with the final CO_2 dragster challenge. Due to the number of learners that participated, coupled with the logistical requirements, this event was hosted at a larger venue, with the necessary equipment. This event was deemed successful because of the large number of learners that participated, of which the results are provided below. Due to this success, it was decided to host this final project event again in 2017. In addition, the Arduino microcontroller development board was included as an extra category, which allowed learners to develop industry required C-based programming skills.

The engineering aim was to introduce electronic design and microcontroller programming skills. The user-friendly text-based PBASIC programming language could be used to program the Basic Stamp II microcontroller. There was also a basic graphical block type program that the students could use to control the AfrikaBot robot. This enabled eager learners with little knowledge about text-based programming, to participate in this project challenge. The mechanical and electronic microcontroller printed circuit board had to be assembled by the students.

Physics project: CO_2 Dragster Challenge

An engineer must have good practical knowledge of physics. The study of matter and its motion related to energy and applied force, is one of the important physics fundamentals that an aspiring engineer must practically understand.

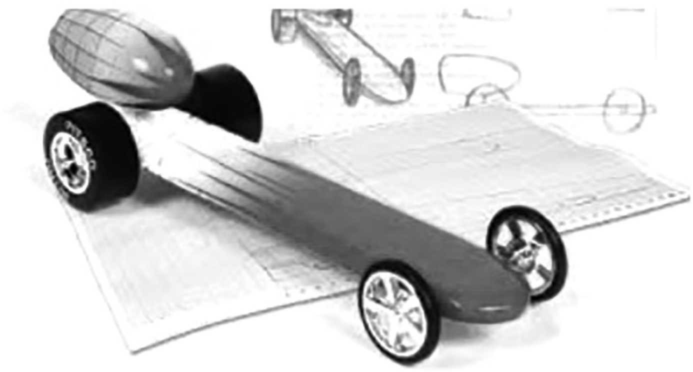
For years, physics has been incorporated in the South African secondary school curriculum as in most other countries. In most South-African secondary schools, this is an elective module from grade 10 onwards. Learners who choose physics from grade 10 onwards already show an interest in pursuing a career either directly in the physics field, or in the engineering field.

In this project, learners build a small dragster car to demonstrate physics fundamentals of motion where a CO_2 canister was the only active propellant used. The specifications of the dragster are as follows (UJ - CO_2 Dragster Challenge Rules, 2015):

- Total dragster length must be less than 305 mm, with total dragster height of 80 mm at the rear with wheels and a total width including wheels of 90 mm.
- Total dragster weight must be more than 75 g (excluding CO2 cartridge).
- Must have two axles.
- The hole for the cartridge must be at the rear of the car, with a minimum of 3 mm thickness around the cartridge and must be parallel to the racing surface. The depth in from the rear should be 50 mm.
- The dragster must have two screw eyes at the bottom so that the track safety string can pass through easily. The screw eyes must not touch the racing surface.
- The dragster must have four wheels made only from plastic and must be able to roll freely.
- The dragster bodies must be manufactured by hand and the material must be either plastic or wood. Power tools may be used, but no computer-controlled machining may be used.

An example of such a CO_2 dragster car is given in Figure 2.

Figure 2:
Example of a CO_2 dragster car



It can be clearly seen from Figure 2, that there are no motorised or electronic components on the CO_2 dragster car. The only source of power is a CO_2 canister, which is placed securely at the back of the car. Great emphasis is placed on safety, as can be seen in the list of requirements. A learner with no specialist knowledge should be able to design and construct a dragster car and use it effectively on a 20-metre race track. The only time the CO_2 dragster car is propelled, is when the track is made available on a scheduled race day. The learners then practically observe and experience the physics of motion, force and aerodynamics.

The 20-metre race track length includes sensors at the start and end, with other electronic equipment, to measure travel time. The time taken from when the CO_2 dragster car is launched, until it reaches the end of the track is measured accurately. A safety line passes through the screw eyes mounted at the bottom of the dragster car and spans the whole 20-metre track length, to keep the car on the track when propelled by the punched rear CO_2 canister.

The model adopted requires learners to interact and engage with university staff members during each event. The learners also test out their dragsters cars on the actual race track made available to them before the event starts. Depending on the number of groups in an event, a minimum of one to a maximum of two practice sessions is allowed per event.

There are at least four staff members present at each event. One staff member inspects and ensures that the dragster car meets the required specifications. Another staff member logs the race times and determines the overall winner. A race director coordinates the students according to registered sequence and a track manager assists students in the logistics of placing the dragster cars correctly on the track.

The aim of this STEM-based project was to introduce in a fun way, the fundamental basics of aerodynamic motion. The students also had to design and construct the CO_2 dragster car to meet the required specifications, by using workshop hand tools. A large group of learners participated as discussed in section 6, because this project challenge was open to all age groups at a secondary school level.

PLC project: Unitronics Weather Station

The Unitronics Weather Station is a more difficult challenge for students and requires more resources such as training from academics, financial support and contact time. There are also a lot more engineering principles that need to be learned compared to the CO2 dragster challenge. A Programmable Logic Controller (PLC) is used in this challenge and the students must learn how to program it, using Ladder Logic.

Continuous weather monitoring is critical to forecast weather patterns and enable people to adapt and plan ahead. In primary and secondary schools, learners are taught about the effects of the weather in their subjects. Learners also watch and learn about weather forecasts when televised.

In this challenge the learners are required to build their own weather station, to monitor and log certain weather parameters over a given period of time. Learners can choose which parameters they want to monitor, but they must also research a way to sense these parameters. Teams of three to four learners were allowed to compete. Figure 3 describes the more common weather parameters that can be monitored:

Figure 3:
Flow diagram of the PLC Project: Unitronics Weather Station

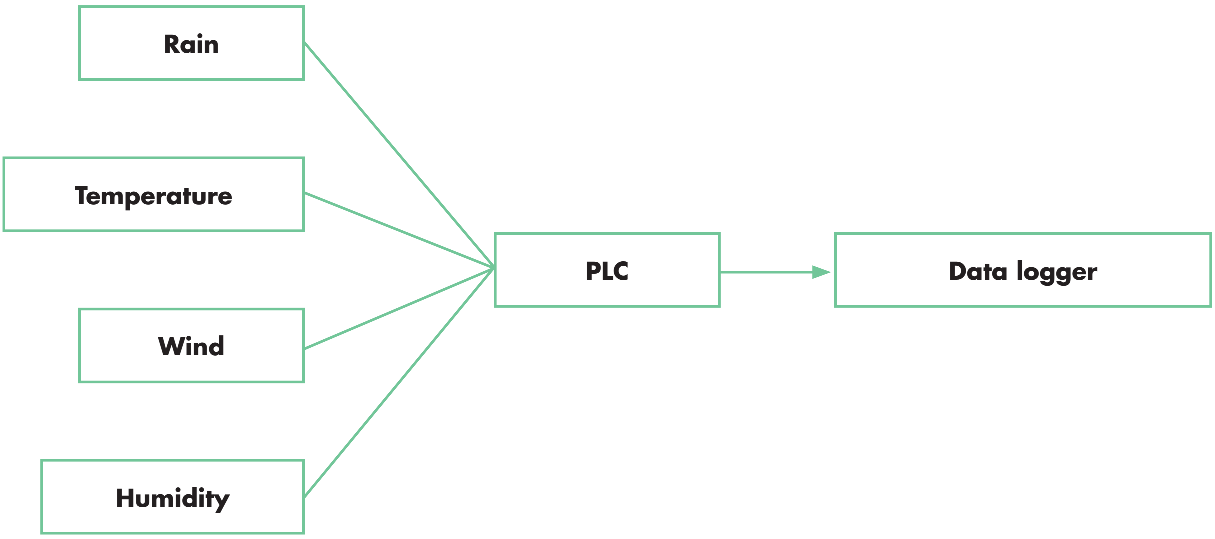


Figure 3 describes the typical elements that make up a weather station. These measurable elements are rain, temperature, wind and humidity. There are other elements that can be measured, but for the sake of time and funding, most learners chose to implement these four elements. More parameters could be monitored by the weather station, for example the UV intensity, but for logistical and financial reasons, we proposed that the learners only monitor the more common parameters. Spending for this challenge was limited to around R2000 (~153 USD). If the teams spend more than this limit, they were penalised according to an assessment rubric.

The University sponsored and also found sponsorship for two items for each team. A 230V AC to 24V DC power supply and a Unitronics Vision (V350) PLC were supplied to each team for this challenge. Listed below, are some of the most important rules for this project.

- Preferable three to four learners in a group and they may be in any school grade.
- Group members may only be school learners and we encourage an educator to mentor the group.
- Industrial support was encouraged, but the main sensing functions should be designed and developed by the learners.
- The weather station should be modular to simplify transportation.
- Correct electrical safety measures must be implemented.
- Groups, who complete the project and presented at the final project event day, may keep the sponsored power supply and PLC. Those who do not complete the project must return the power supply and PLC afterwards.

Part of the challenge was to monitor and log sensed weather parameter data over a period of time. The learners had to demonstrate this logging feature by showing the acquired data in an appropriate format, since it was also evaluated on the assessment rubric. Each institution that decides to host a similar challenge, must set up their own assessment rubric to meet their goals. The important assessment criteria were discussed with learners and teachers. A successfully completed weather station project, becomes the property of the school or college and could then be implemented in science and technology subjects as part of the curriculum. The possibility of sponsorship was more likely if one of the main aims of the challenge, was to introduce PLC programming at secondary school level.

In most secondary schools, that conduct computer studies, only a beginner's level of C programming is taught. However, programming is not just understanding the syntax, but also developing a thorough understanding of how to design a logical algorithm. There is simply not enough time dedicated to teaching this fundamental skill. Logical algorithm design itself takes some time to thoroughly understand and grasp. However, there is less syntax to learn in Ladder logic than in C programming, which allows students to focus more on logical algorithm design. There were some failures (36% failure rate) and therefore it was decided to terminate this project mainly because of underfunding and the difficulty level.

The aim of this STEM-based project is to introduce and develop industrial PLC programming language skills. PLC interface sensing circuits, also had to be researched and constructed by the students. The sponsored PLCs was programmed using a combination of ladder and function block logic. This type of programming is still the most popular commonly used industrial PLC programming language.

GENERIC MODEL AND IMPLEMENTATION

In this section the underlying model developed to administer the project challenges, is defined. The adopted model is illustrated in a graphical diagram format with no specific reference to any project.

Formulation of the generic model

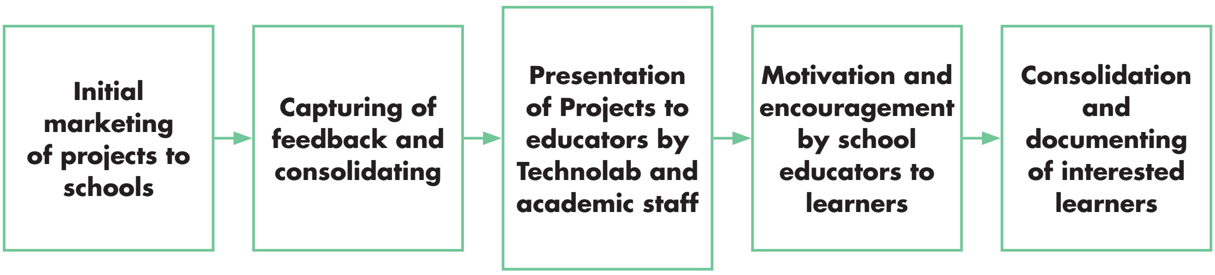
In Figure 4, the overall general adopted model can be spilt up into three main phases.

Figure 4:
Flow diagram of the first phase of the generic model for community service projects

During the first brainstorming phase as shown in Figure 4, it is extremely important that a proposed project must receive industry support, to ensure sponsorship. However, the main aim is to select a project challenge that will have an engineering related outcome.

Fundamental physics and engineering related principles were incorporated into all three community engagement project challenges. Basic electronic and programming skills were introduced and incorporated into the Weather Station and Robotics project challenges. The flow diagram shown in Figure 5, expands on the second implementation phase of the community engagement project.

Figure 5:
Flow diagram of the second phase of the generic model for community service projects

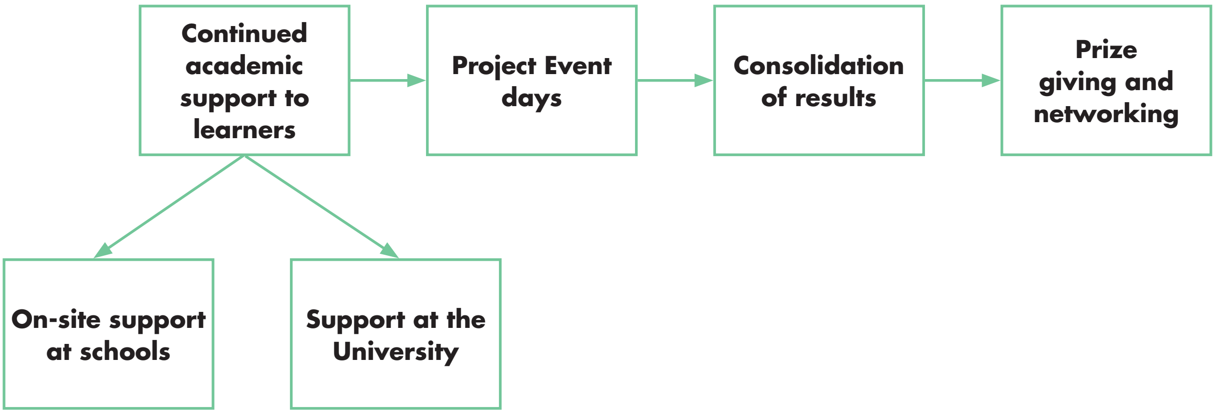


At the beginning of the year, possible project challenges are discussed and then proposed at targeted secondary schools, to determine the interest level and possible participation as shown in the first element of Figure 5. The initial project challenge presentation must also appeal to secondary school educators, so that they will be interested in motivating students to participate. The Technolab administration staff then records possible ideas and suggestions provided by school educators that will be considered by the academic staff involved in the community engagement. The project challenges are then adapted and finalised so that it can be presented by academic staff in a more detailed format to school educators. During this phase, academic staff will answer technical related questions including logistic and engineering component sourcing related issues. Where possible the university academic staff will also engage with the industry in an attempt to acquire sponsorship, in the form of required engineering components that can be handed over to participating schools.

The last two phases are then administered and coordinated by the secondary school educators. However, schools fail to participate if learners are not interested, no matter how enthusiastic school educators may be. One way to ensure participation and interest is for the school educators to include the project challenge as a required activity in their subject curriculum. Finally, the participating learner details are documented and sent through to the Technolab administration staff, so that the requirements for project event days can be organised.

The flow diagram shown in Figure 6, expands on the third implementation phase of the community engagement project.

Figure 6:
Flow diagram of the third phase of the generic model for community service projects



To ensure successful participation, continued support and assistance from the university academic staff must be provided on a regular basis to learners and school educators during the first part of the final phase as shown in Figure 6. Depending on the logistical requirements and the availability of academic staff, the support session can occur at the University or on-site at the secondary schools. This part starts immediately after the student groups have been finalised and is ongoing until the actual project event days, which occurs in the latter part of the year. The project event day, consolidation of results, prize giving and industry networking is the second part of the final phase.

The learners will then compete against each other on the final project event day. Learners at secondary schools as well as educators are pressed for time during the latter part of the year and therefore cannot dedicate a lot of time towards the final project event day. Therefore, it is essential to anticipate and plan ahead for any logistical requirements, to ensure that the final project event day is successfully completed. It is important for academic staff to consider using industry experts as evaluators on the final project event day. Most university engineering departments have strong industry collaboration ties and should therefore involve industry experts at top level industry positions in medium to large scale companies. In this way, young talent can be identified by industry experts before the learner starts tertiary education. Opportunities in the form of scholarships and even post-graduation employment can be secured. This is also an excellent opportunity for learners to network with industry experts, so that learners can feel more at ease and confident with their decision to study an engineering-related discipline.

Logistical implementation of the model

The first step in the entire process of hosting STEM-based projects is to present a specific engineering project challenge to school educators. The drive is for the school educators to collaborate with university academics and administration staff. In the end, school educators can provide parents and learners with more knowledgeable guidance in the enrolling decision at tertiary studies.

After this initial presentation, the project details are then provided to the educators and learners. This can be done by the educators proposing the project formally to the learners or through the academic staff of the Technolab; either way, a hands-on approach is taken.

The next step is to document and group the learners who want to participate in the engineering project challenge. One of the schools decided to make the CO2 dragster challenge part of their physical science curriculum to emphasise the fundamentals of aerodynamic motion. This approach generated great interest in the project because this is a more practical fun way of providing education to the learners. The school educators send the names of the learners and group names to the dedicated non-academic personnel at the Technolab.

The school students then start working on the projects. The academic personnel of the Technolab have dedicated time to teach learners the necessary skills and concepts to be able to complete the projects successfully. Since the academic staff are mostly busy with other responsibilities, their schedule is provided to the administration of the Technolab. In conjunction with the educators at the schools, timeslots are arranged where the academic staff then assist the students. The venue where the students are assisted can vary depending on the operational requirements of the University and the schools. More often than not, the academic staff simply drive to the school and provide assistance.

Programming skills were required for both the AfrikaBot and Weather Station project, which does not always form part of the typical taught curriculum at schools. However, some schools do have programming as part of their computer science subjects, but this requires a qualified educator, which most schools cannot afford. Also, mostly text-based C-programming is taught at schools, but there are other industrial programming languages actively used today in the industry. For example, most PLCs in the industry are programmed using either ladder or function block logic, or even a combination of both. In the weather station project, the Unitronics PLC was programmed using a combination of ladder and function block logic. Learners found this visual graphical type of programming language a lot easier to learn than text-based C-programming code.

From the middle to the end of the year, the Technolab administration staff organises the various events where the academic staff will be present to facilitate the competition's events. Of paramount importance is the safety of the learners, therefore a considerable amount of time is spent to ensure that all applicable safety precautions are taken.

However, for the Weather Station project, we provided an assessment rubric sheet to three independent industry-qualified experts, to evaluate the student group project. The winning teams for all three project challenges received awards in the form of essential engineering tools.

RESULTS

In this section, a detailed breakdown of the participants of each event is given. For the AfrikaBot and CO2 dragster challenge, all the participating learners or groups who successfully completed the challenge were interviewed as they completed the challenge. All these learners cited that the challenges were fun and they gained valuable engineering knowledge not normally taught at secondary school level.

For the Weather Station challenge, only eight teams out of the 22 participating teams expressed their willingness to participate in this challenge again. The other 14 participating teams expressed that even though they enjoyed learning Ladder Logic programming, which is not taught at secondary school level, they found the challenge to be too difficult and time consuming. In addition to this, the financial costs involved were also cited as a reason not to participate again. Of the 22 teams that participated in 2014 and 2015, only four teams participated in both years where they were allowed to upgrade their implemented weather stations. In addition to this, there were a total of 14 successfully implemented weather stations.

For the AfrikaBot challenge the results are tabulated below:

Table 1:
AfrikaBot 2016 results

Category	Number of robots	Successful completion
Grade 8-9	14	10
Grade 10-12	24	10
Undergraduate	7	5

Table 2:
AfrikaBot 2017 results

Category	Number of robots	Successful completion
Grade 8-9	17	16
Grade 10-12	24	16
Undergraduate	15	8

Between 2016 and 2017, as shown in tables 1 and 2, it can be seen that there is growth in both the number of participants (24% growth) and the number of robots successfully completing the challenge (60% growth). This includes completing the track in a given time of 60 seconds. Each participant had two extra tries for each run and each participant had a total of three runs.

In 2016 and 2017, a total of 53 and 70 entries were received respectively of willing participants for the AfrikaBot challenge (indicating a 32% growth).

For the CO_2 dragster, the results are as follows.

- In 2014, one event was hosted at one school with 22 cars.
- In 2015, three events were hosted at the same school as in 2014, but the first two events were practice events. For the first and second practice event there were 40 cars. For the final event, there were 49 cars. All three events were hosted on successive days.
- In 2016 the challenge was expanded to two more schools hence three separate events were hosted. For the first event there were 22 cars. For the second event there were 55 cars and lastly for the third event there were 25 cars.
- In 2017 there was four separate events at three different schools. For the first event, there were 36 cars. For the second event, there were 33 cars. For the third and fourth event, there were 35 and 25 cars respectively.

Table 3 documents the total number of successful cars in each year from the recorded data.

Table 3:
CO2 dragster results

Year	Total number of participants
2014	22
2015	129
2016	102
2017	129

CONCLUSION

Engineers are an essential part of developing the South African economy. STEM-based projects all over the world attempts to alleviate several underlying issues relating to attracting students into engineering, as a career choice. The current secondary schooling in the South African system lacks in that it does not introduce engineering principles to entice learners to enrol for engineering studies. By using university academics to provide their time and knowledge to enable learners to develop and implement required knowledge and skills outside of their current curriculum at secondary schools, learners were enabled to participate in the STEM-based project challenges.

By availing time and knowledge to learners in a practical format, the engineering discipline becomes more accessible, exciting and understandable to learners. This will help learners to make a more informed decision when enrolling for tertiary education. The model presented in this paper is a contact-based approach to host STEM-based projects in a way that entices learners to study a more challenging but also exciting engineering discipline.

The impact of this model is the growth seen in both participation and successful completion rates of these project challenges. As an extension to the implementation of this model, questionnaires should be developed and implemented to validate numerically the impact. In addition, the gender and age of the participants should be recorded to analyse and understand of the greater impact of the proposed model in this work. STEM-based projects should also focus on encouraging females to participate in order to change the perception of learners towards STEM-education (Nair et al., 2017; Gaitan-Leon et al., 2017; Hurlburt et al., 2013; Sharma, 2016). The hope is to make use of this presented model more widely, to increase engineering graduates in the future and thereby address the gap of supplying qualified engineers to grow the South Africa economy.

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