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R2T2 : Robotics to Integrate Educational Efforts in South Africa and Europe

Abstract

Keywords Rescue, Educational Robotics, Thymio robot, Space Robotics, Programming

1. Introduction

The South African government is working at improving Science, Technology, Engineering and Mathematics (STEM) interests within schools for scholars to become excited with these careers that are limited in the country. As mechatronics engineering and robotics are the integration of mainly mechanical, electronic and computer engineering disciplines, it allows for the skills in these areas to be learned. Robotics have been showed to be a great tool to teach abstract concepts from mathematics to mechatronics [1].

Different factors have an influence of scholar's learning activities within Africa, which include toilet facilities, building infrastructure, computer equipment facilities and laboratories, libraries, and learning teaching support [2]. Furthermore, poverty, poor housing, inadequate skills development, lack of energy sources, inadequate drinking water and sanitation, poor communications, poor education and training, lack of transport, lack of sporting and recreational activities and cultural deprivations, are only a few factors that have created disadvantaged scenarios, of which Apartheid is often to be blamed [3]. Yet, after 21 years after Apartheid, there is not necessarily an improvement in these conditions, but often a degrees in the improvements of the conditions.
Many of the above mentioned problems are vastly related to the lack of engineering skills. Improving on these skills, especially which correlate with mechanical, electronic and computer engineering, can allow many people to improve their living conditions. Many times these living conditions can be improved on by a person who have the interest to learn and solve their problems. It has been evident of such scenarios with people in Malawi who have no education, yet were able to learn the skills and thus allow themselves to build windmills, as a means to generate electricity and pump water [4].

With the use of Robotics, South Africa has pursued education events such as the First Lego League South Africa [5], First Tech Challenge South Africa [6], the World Robotics Olympiad [7], and participation to the RoboCup Junior contest [8]. These events have shown to be very beneficial for students in terms of motivation in learning [9]. They often encourage self-autonomy and collaboration within each team of participants. Sadly these activities and events are often pursued with the upper-class schools, who have the computer facilities, an internet connection, and teachers who have been enthusiastic to educate the students with resources above those in the normal syllabus. For instance some scholars are able to attend robotics at the Cape Town Science Center as an extra mural activity, yet payment is required to be made to attend these sessions [10].

These events are organized also in Europe, rising some similar issues but in another context. Robot competitions, in Europe, attract only participants already interested in STEM topics, and have very few impact on most people [11]. Moreover very few women are participating in these events, contributing to a gender gap on education about technology [11]. In some extent the elitist aspect of these competitions is similar to South Africa, even if expressed differently. Another common characteristic of the existing events is that they are all based on competitive activities. Existing surveys suggest that collaborative activities could motivate a larger public [11].

To summarize, both in South Africa and Europe it is hard to bring robotics into schools, for different reasons. In South Africa the economic factor plays a more important role, but the European comfort of the teachers is also a barrier to changes. In both realities it would be interesting to have activities that generate a broader interest, better motivate the teachers, can reach a broader public and are economically affordable.

There exist many different robotics kit available for STEM education. The Thymio II robot has been indicated as an appropriate robotic platform to pursue STEM in Africa [12], as it is an open source platform with a sensory system that include a microphone, IR proximity sensors, temperature sensor, odometer and accelerometers, with the use of open source programming language, Aseba [13]. The Thymio robot has been broadly spread in schools in Europe[14], and used as a tool for teaching many topics, from physics [15] to computer science [16]. Even though the Thymio robot has been one of the more expensive educational robots that have been used in Africa [12], it has been cheaper than the Lego Mindstorm EV3 robots, and it has been one of the best robots with processing, sensors, deployment, development and maintenance.

This paper presents an education activity, called R2T2, addressing the issues above by using the opportunity offered by the Thymio robot. In opposition to the existing events, R2T2 focus on a collaborative task, based on a rescue operation where several groups need to cooperate. To gain attractiveness, the rescue scenario is set on a mars station. Therefore the participants access to the installation remotely, which is an interesting economical aspect, as the expensive installation is shared and nobody needs to travel. Moreover this allow to bring together people living in very distant places, with different cultures and technical background. In this case, we used this possibility to bring together European and African children, which creates very interesting interactions, from emulation to help. This scenario allows also to add and justify an key aspect of the interaction with the robots: the delay between command to the robot and video feedback. This delay is necessary to ensure the video streaming but is also realistic in respect to an operation on Mars. From an education perspective, this delay defines the way participants can interact with their robots, excluding the possibility to remote control the robots and forcing the participants to program them. Finally the R2T2 rescue scenario requires the coordination of 16 teams controlling 16 robots placed in the Mars station, and therefore allows to include in the event other activities than robot programming: coordination within the team and with other teams, communication, planning, validation of distant results, etc. This broad spectrum of activities enable the inclusion of teachers from various disciplines and participants with different interests.

The R2T2 event took place in November 2015, bringing together 100 participants from Europe and Africa. A survey allowed to spot the interesting value of this event, as well as the specificity of the European and African participants.

After this introduction, the next section introduces the Thymio robot and the R2T2 event. We introduce then the survey made among the participants and the analysis of the results. The last section includes a discussion and the conclusions.

2. The robotic infrastructure

2.1. The Thymio robot

The Thymio II robot, simply called *Thymio* in this article, is a desktop differential drive robot (see figure 1). Its size is $112x110x55$mm, and its shape allow to place it on the table in several positions, so that it can become something else as a mobile robot. Also its white color has been chosen to keep a look that is age and gender neutral [17]. Despite its affordable price (around 130$), Thymio a an interesting set of sensors, listed in figure 1. A very specific feature of Thymio is in the high number of LEDs placed over the body, allowing to visualize the activities of the sensors and creating a high interactivity with the user. At the software level, Thymio supports the ASEBA framework[13] consisting in a virtual machine within the robot and a very flexible communication infrastructure allowing to program the robot and run debugging tools over many several communication channels. In the case of the R2T2 activitiy, we will mainly used the possibility to connect to the robot from a computer through a radio protocol, and then use a switch to enable to connect from anywhere on Internet.

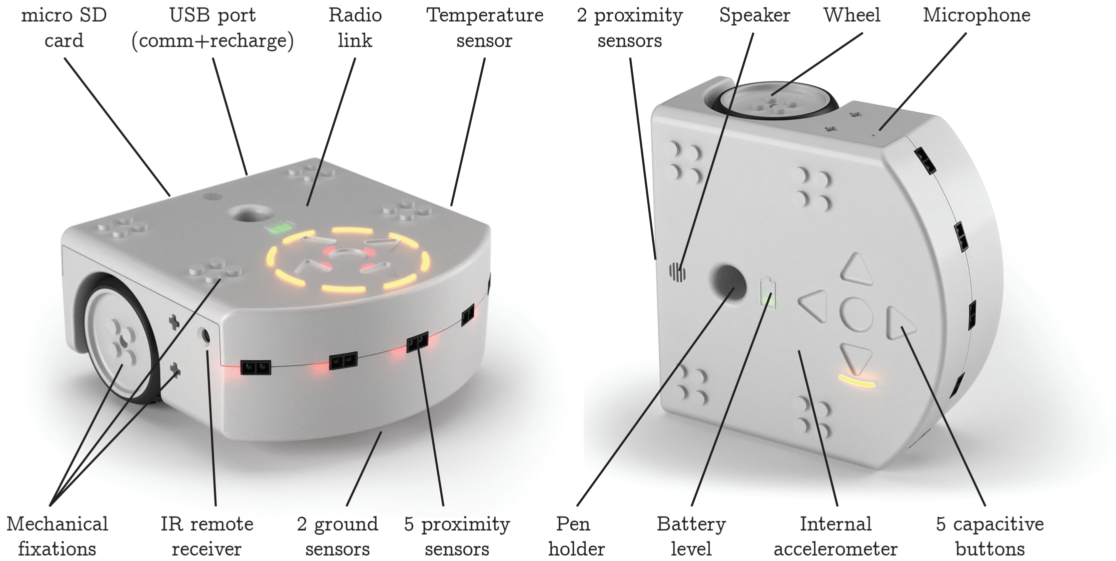

Figure 1. The Thymio robot and its devices.

There are several programming interfaces that can generate code for the onboard ASEBA virtual machine. The main three are:

1. A text based environment, illustrated left in figure 2, enabling the use of a simple matlab-like scripting language.
2. A graphic environment, called *VPL* and illustrated right in figure 2, allowing programming also for non-readers children.
3. Scratch and Blockly environments that use a graphic layout to place text-based code.

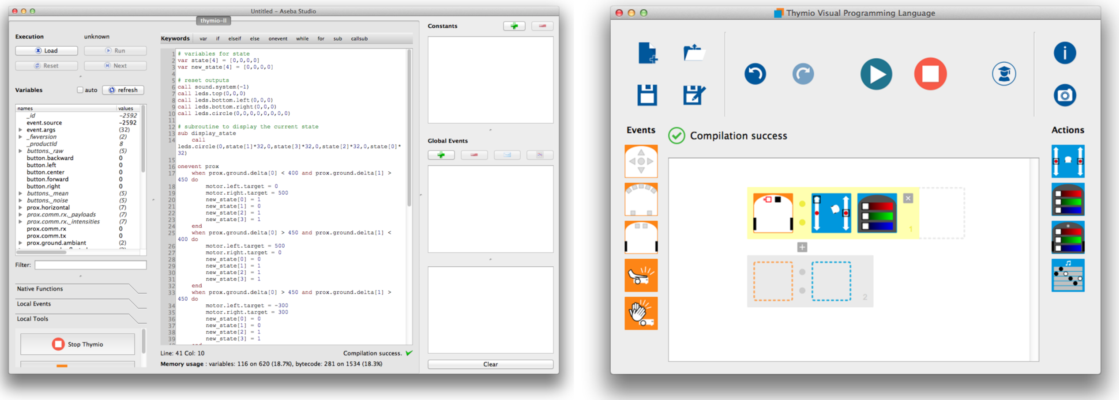

Figure 2. The two main Thymio programming interfaces: On the left, the text interface, allowing variables real-time visualisation, debugging etc. On the right, the graphical interface for beginners, enabling the definition of sensor-actions associations that can define a behavior.

2.2. *The R2T2 concept*

The R2T2 concept aims at bringing together, in a common event, a large number of children from everywhere on the planet, and in Africa in particular, in an activity that motivates them to learn about STEM. To keep the budget as low as possible, one solution is to let the participants access remotely the event and the robots, saving the money for travel and saving the cost of the central installation. A well-known application based on remote operation of mobile robots is space exploration. For children, this type of use of robots is very appealing as it is related to news (Mars exploration) and movies ("The Martian", for instance). Therefore we decided to create the scenario around space robotics.

Once the environment and the mode of access to the robots is set, the next question is about the tasks to be solved. Because existing surveys showed that collaborative activities could motivate a larger public than competitive ones [11], we decided to have a collaborative instead of a classical robot competition. Among the applications that are addressed at EPFL in the National Center for Competence in Research "Robotics" supporting this initiative, search and rescue has a central role. Therefore we built the following R2T2 story:

> We are in 2032. A meteorite has damaged an important Martian power station and we need to assess the damage and restart the main generator. We have 16 robots on site. Each robot can be controlled by a team of engineers and space experts from Earth. Between Mars and Earth there is a delay in video transmission (between 3 minutes when Mars is closest and 21 minutes when Mars is farthest from Earth in its orbit) and direct remote control is impossible. Therefore the Earth experts need to program the robots to solve the task. We recruited 16 teams of experts from Switzerland, France, Austria, Italy, Russia and South Africa.

We indeed recruited 16 teams: 8 from Switzerland (two from Sion, two from Geneva, one from Lausanne, Fribourg, ZÃijrich, and Founex), one from Italy (Borgonovo Val Tidone), four from France (Ayguemorte-les-graves, Floirac, Talence, Vandoeuvre les Nancy), one from Austria (Graz), one from Russia (Moscow) and one from South Africa (Durban). For this first edition we decided to take only one team from Africa, using a network of known partners to test the concept.

Each team could access and program a Thymio robot located around the Mars station located in Lausanne. A video feedback was provided by live streaming on YouTube. On YouTube, a chat is provided to exchange messages between the teams.

The Mars station (see figures 4 and 5) is supposed to be a power-plant with a central generator surrounded by four identical sectors, called A, B, C, and D. Each of them is constituted by an obstructed main door, a back door, a control zone and a generator observation zone. Four Thymio robots are located outside of each sector. Their rescue mission consist in 5 phases:

1. Entering the station. This phase requires to have one of the four robots entering by the back door and pushing the block obstructing the main door. Then all robots can enter into the control zone.
2. Finding the control spots. In the control zone there are four white dots on the black floor. Each robot need to place itself on one of the dots to activate the access to the generator.

Figure 3. Artistic illustration of the R2T2 space rescue scenario.

3. Looking to the generator. Once the access activated in all four sectors, each robot has to place itself in a slot around the generator. Each slot has a small window allowing to look into the generator. By using a proximity sensor, each robot can detect when the rotor of the generator is in front of the window.
4. Evaluate the generator speed. In this phase each robot switch on a light when it sees the rotor of the generator, and switches off when it does not see it. This allow to visualize the rotational speed of the generator from outside.
5. Restating the generator. This final phase is purely spectacular, as the generator start spinning faster and faster, showing the success of the mission.

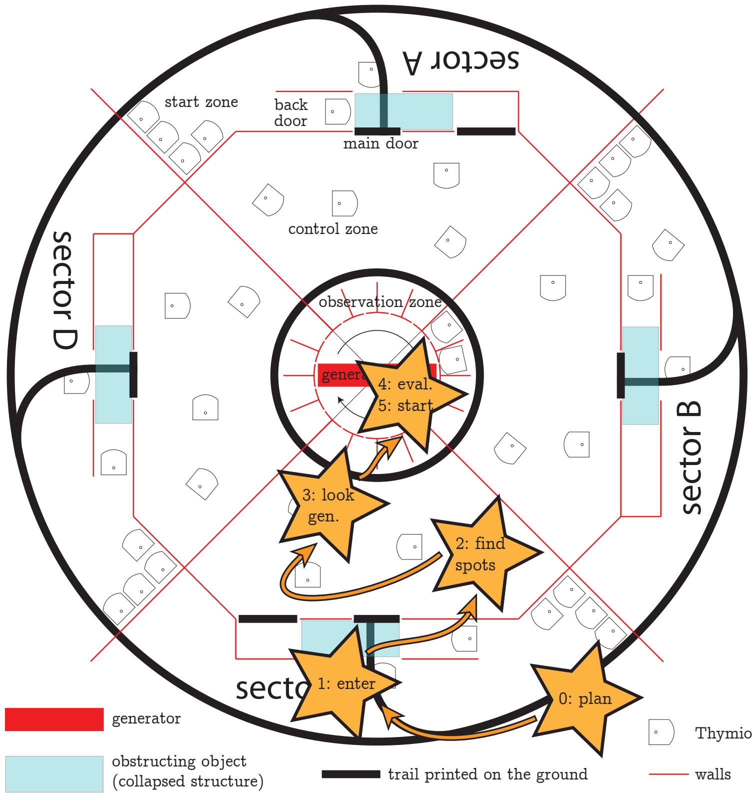

Figure 4. Map of the Mars station with the five phases of the rescue mission.

To provide the feedback to the user, five cameras are placed around the station (see figure 5 left), one for each sector and the fifth providing a top general view (see figure 5 right). In the first three phases the participants can get a detailed view of their sector through the specific camera of their sector, then they can get an overview from the top camera. Each view has an associated chat window, allowing the exchange of messages between the people active in this area.

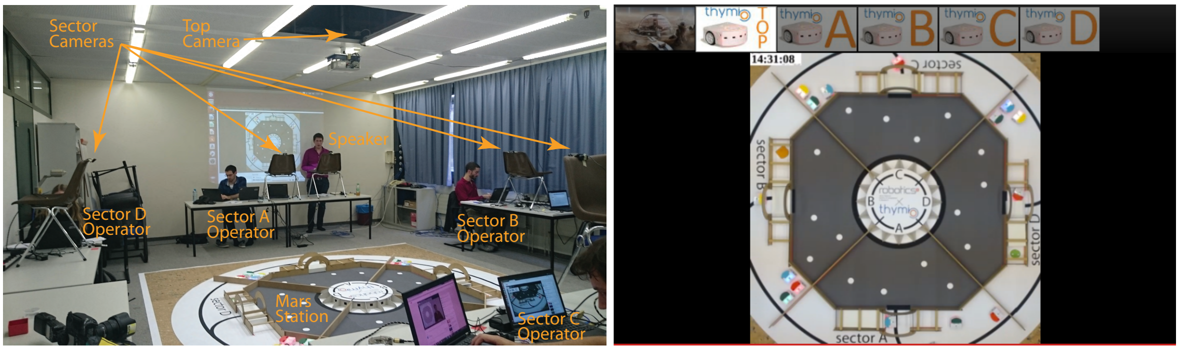

Figure 5. Physical setup in EPFL Lausanne and view of the station on YouTube.

The technical infrastructure supporting the video streaming and the control of the robots is presented in figure 6. Behind each camera there is a server encoding the video and streaming it to the YouTube servers. The whole process of encoding, transmitting to the YouTube servers, dispatching to YouTube clients and visualizing, introduces a delay of 30-40 seconds. The same computers in charge of the video streaming of the four sectors are also used as bridges for the robot control. Indeed the robot control comes from the participants through Internet and is then routed to the robot using a radio connection. Through this channel, each participant can both visualize robot data in real time, and send motor commands or programs to be executed.

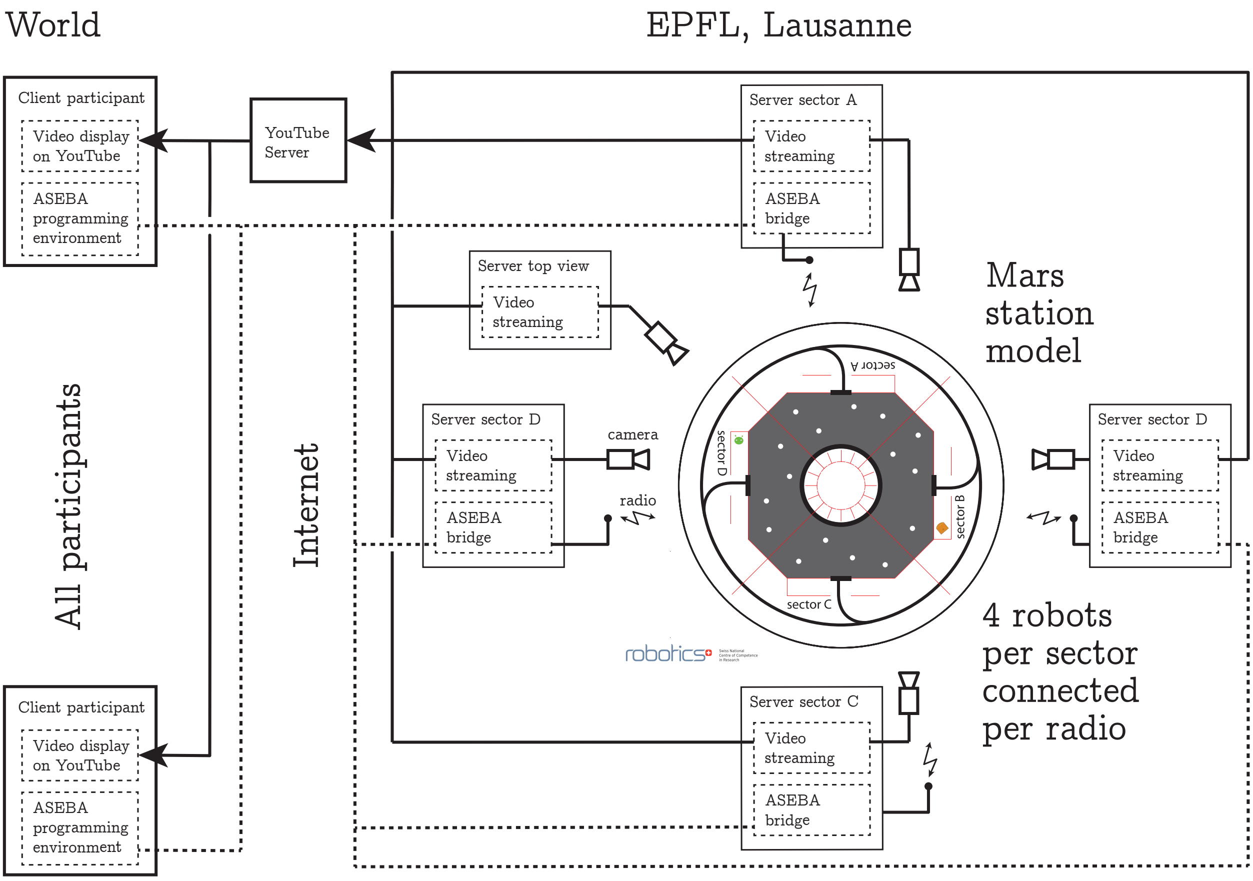

Figure 6. Infrastructure of the R2T2 experiment.

3. Survey among the children

: results

4. Discussion and conclusion

Government schools in South Africa did not readily offer French as a language course and a high profile secondary school was therefore selected for participation in the event, in order to meet the requirements of having at least one team member who was fluent in French. The theme of the event attracted the top students from various grades within the selected school. These students formed the team that participated in the event and all students in the team had prior experience with programming and hobby kits such as the Arduino Uno programmable controller. The training of the team was made easier due to the fact that the selected students had prior programming knowledge. A set of instructions was supplied with the Thymio kit along with a training manual which introduced the user to the various functions and capabilities of the robot. The method used to train the students involved implementation of the training manual and this was supplemented with allocating tasks specific to the environment in which the team worked. Table âĂę lists the progression of the training performed with the students. This progression followed the installation of the software onto the individual stations used by the students. The team was given a set of four robots and an additional robot for the teachers to experiment with.

It was also observed that the initial team of four members had expanded to twelve as the initial team took it upon themselves to train their peers who showed interest.

The R2T2 event required a lot of preparation. Except that the equipment had to be setup for the event, the communication and streaming of video was challenging, due to the limited internet bandwidth. At the South African event were two YouTube video streams[1], which was very choppy and the sound was not streamed and recorded properly, due to the limited bandwidth. More video streaming were considered, but were cancelled when it was realized that the YouTube footage was not recorded properly.

The two YouTube streams from EPFL, which represented the Mars environment and the scenario, were projected, one being the global view, and the other being the specific sector view (Sector D). The delays of the videos that were created at EPFL, to represent the delay in communication between Mars and Earth, was very interesting in the way that the participants had to plan the challenges. The participants often wanted to stop the robot, but then the instruction would take time before the robot received it. In saying this, it was observed that the YouTube stream from EPFL had an additional lag, due to the limited bandwidth. Viewing the same video stream through a smartphone and a GPRS signal, showed different video footage and were thus out of sync. This was challenging for the participants as the video feedback and thus the robot response was not consistent.

The participants thought that they could give the Thymio robot instructions and get things working the first time, even though they were advised not to do so. They learned very quickly to follow the advice, and to work in a team, to first simulate instruction on the robot they had within the lab, before sending the instruction to the robot. After the participants changed their approach, it indicated that they were more successful with attempting the challenges.

There was a problem experienced with the communication with the Thymio robot form South Africa, in that the robot did not respond to instructions. The reason for the malfunction is uncertain, yet after numerous attempts to send the instruction, and realizing that the robot did not perform after the expected delay in transmission, the connection was reset by EPFL.

The participants were frustrated at times when things did not happen as they expected, yet once they realized that they had to solve the problems using smaller steps and in a sequential manner, it showed to be more successful. It has been found to be the most challenging aspect with the teaching of robotic systems within South Africa, with the sequential steps in the programming of the robots. It is found that the scholars are able to grasp the mechanical component quite easily, as they have been exposed to building structures, whether it is with sand, stones, sticks, or even more advanced material such as building bricks, Lego blocks or metal materials. The understanding of the electronic component is grasped a little more difficult, yet with the scholars being exposed to more electronic systems and being taught electrical circuits from a young age, they are able to connect the different components and modules together. The aspect that scholars have difficulty with is the programming. Even though they are taught of planning with flowcharts and pseudocode, and indicated that they must think of themselves being the robot and the steps that is needed to be followed, the scholars have a difficulty with sequential instructions. There are many factors for the scholars to have a difficulty to understand this concept, and it could be due to everything happening lately automatically, with less problem solving, as technology has developed, and also due to scholars not being exposed to programming at a younger age. Typically, within South Africa, some scholars are only exposed to programming for the first time in grade 8, otherwise only in grade 10 should they have taken computer science as a secondary school subject. It has also been found that some students are only exposed to programming when they reach university level, as their school did not have computer facilities and limited technology equipment. It is believed that this hurdle will only be overcome once programming skills are to be taught from the beginning of the scholarâĂŹs school career, which can be pursued with activities such as placing the sequence of event into order with the different activities they need to perform to get to school every morning. Similar activities will make the scholars to have a better understanding with sequential programming in the future.

The learning quality of engineering disciplines has to face several issues in developed countries such as distance and cost or materials which could be address through distance learning [18]. This first R2T2 event showed how the distance in terms of access to technological facilities could be reduced.

[1] https://www.youtube.com/watch?v=sd3tdzocsFY
https://www.youtube.com/watch?v=q5NX98K2ptg

Table 1. Progression of the training performed on selected South African students

Task from training manual	Supplementary task	Observation of students
N/A	Introduction to programming methodology: Students were taken through the process of deconstructing a program into logic, pseudocode and then implementation of relevant programming language. A task was allocated to the team to list the pseudocode and draw a flowchart for the processes associated with making a cup of coffee. Students were then asked to attempt to make the cup of coffee using the instructions they provided.	Students were already exposed to programming and assumed that this was a redundant step. Students found that they could not successfully complete the task when following their own instructions. The reason for the failure was due to the lack of consideration and blatant ignorance of the exact steps required to fulfil the task.
Introduction to programming environment: This step introduced students to the concept of using a visual programming interface as opposed to a text based interface.	None	Students were excited by the ease with which the robot could be programmed using a visual interface. They had only been exposed to text based programming and the graphical representation of functions was welcomed.
Introduction to events and the robotic platform	Students were asked to perform actions based on a command as if they were the robot. This allowed the team to identify the relation between the events and the resulting actions. Students were then asked to associate colours with moods.	Students viewed the platform as a toy initially. This encouraged them to approach the use of the platform in a jovial manner as they were not intimidated by the complex system that lay within the platform. Most of the students associated red with danger and green with a pleasant robot state.
Moving the robot : Students were required to move the robot back and forth	A task was given to students to move the robot around the table on which they worked. This task exposed them to open loop control of the platform.	Students ensured that they provided a flowchart and relevant pseudocode for the robot operation in order to complete the task. It was noticed that they showed enthusiasm in testing their predetermined values and make the necessary adjustments in order to follow the path around the desk. It was at this stage that the students started to display intense focus.
Using the sensors and using states in advanced mode: Students were required to explore the capabilities of the sensory capabilities of the robot. They were required to implement a program that would allow the robot to exhibit the behaviour of a pet. This behaviour relied on the use of states in the advanced mode.	The team was also given the task of programming the robot to behave in the fashion that their personal pets would.	Students took more time in completing this task due to the complexities associated with the safety considerations such as ensuring the robot did not fall off the table. Four unique behaviours were observed which included exploratory behaviour, aggressive behaviour and seemingly irrational behaviour (which students insisted was in accordance with the behaviour of their animals).
Use of range of values and angle options: Students had to experiment with using a range of values for the sensors.	A track was built and robots were required to accelerate uphill and decelerate downhill. Obstacle avoidance was also required.	Students had no problem in implementing the code once their logic and pseudocode was implemented.

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