IEEE CSS Outreach Fund-Final Report

1. Project title. STEM beyond the borders: An Engineering Enrichment Outreach Program-Part II
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4. Funding requested and budget. The total requested was $15,000.00 which included all the materials and equipment for twenty participants of the program, a contingency value and institutional overhead. Some materials were purchased locally while others were ordered online to either the United States or China through Global Web Shopping (GWS). This company provides online purchases to local institutions because it is more secure and efficient than the regular mail post system. Online purchases were sometimes grouped together to reduce shipping and handling costs to Panama. It is important to mention that purchase for items donated to high schools must be separated from items remaining at the university. There was also a raise in costs of some items that were covered by contingency and/or balanced by price reduction in other items. The detailed description of the purchase process at the Technological University of Panama is presented in Fig. 1. Internet shopping follows these steps:
    - A quotation is requested to Global Web Shopping for the items needed for the project.
    - A check is requested for the total amount described in the quotation.
    - Once the check has been issued by Fundacion Tecnologica de Panama (FTP), an order for requested items is placed at Global Web Shopping.
    - GWS provide a receipt for the amount of the check as evidence of the money received for the purchase.
    - After the items arrive to David City, their weight is checked to make sure that it is the same weight specified on the quotation.
    - If the item(s) weighted more than in the quotation, then GWS writes a letter to request the amount to be paid by Fundacion Tecnologica de Panama. This happened in the purchase of items #2, where the quotation showed a total cost of $239.63 for one of the purchases and 664.86 for the other one. However, when the items arrived to Panama, their weight was heavier than expected; therefore, we had to request checks for the amount of $51.47 and $152.28, respectively for the purchases mentioned above.
    - If the item(s) weighted less than in the quotation, then GWS returns money to Fundacion Tecnologica de Panama. This happened in one of the items #3, where a check was issued for $389.33. However, when the item arrived to Panama, they were lighter in weight; therefore GWS returned a total of $66.18 to FTP.
    - If the item(s) is the same as in the quotation, no extra step is necessary.
    - GWS provides an invoice that details the items purchased on the internet store, custom duty, and the shipping and handling service to Panama.

    The final purchase report is presented in Table 1. All the invoices have been scanned and attached in a separate folder.

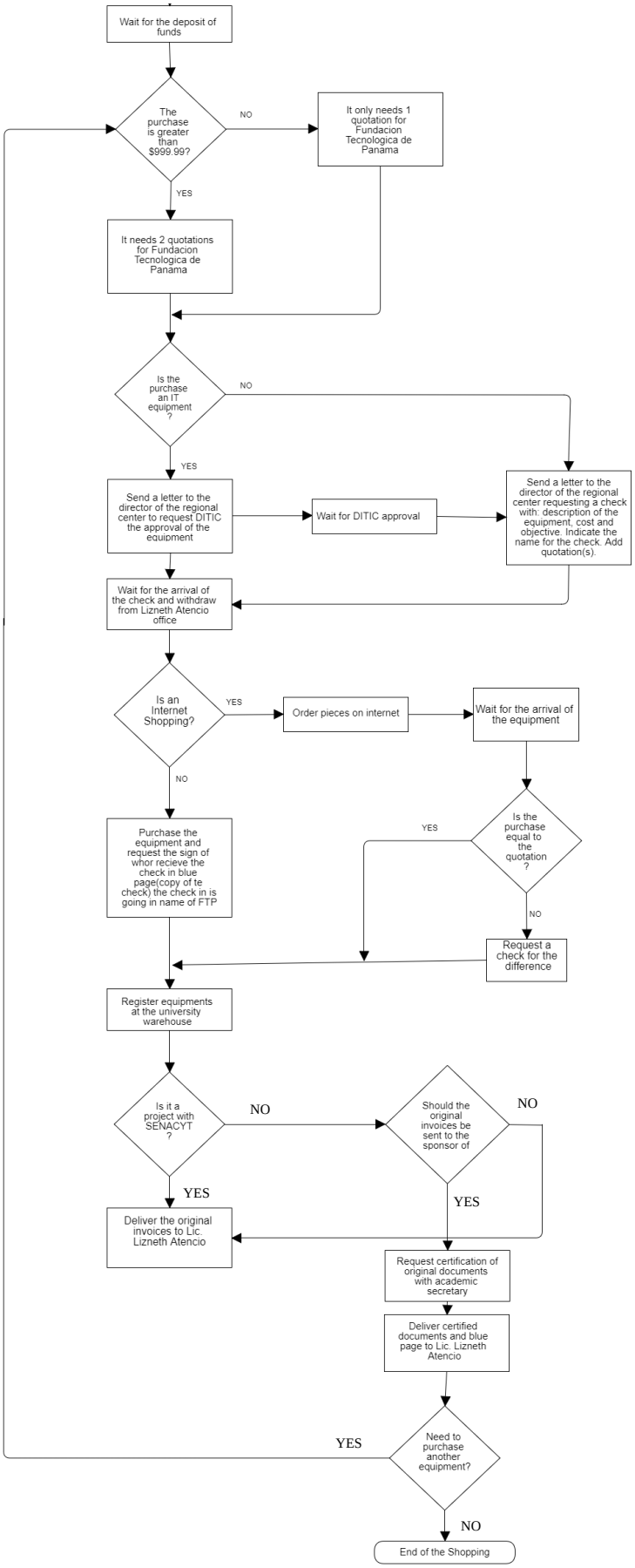

Fig. 1. Purchase Process for Research Projects at the Technological University of Panama

Table 1. Purchase report

STEM beyond the borders: An Engineering Enrichment Outreach Program-Part II

Funded by: IEEE CSS Outreach Fund

Income **$15,000.00**

Expenses **$14,915.86** **Balance**** **$84.14**

Budget Detail				**Expended**
Item #	**Description**	**Vendor**	**Total**	**Total**
1	**Mobile Platform for Arduino Boards**	Robotshop-internet	$ 1,066.39	$ 893.40
2	**Arduino Mega boards, Servo Motors, Ultrasonic Sensor, Base for Ultrasonic Sensor***	Adafruit-internet	$ 1,838.00	$ 1,108.24
3	**Adafruit MotorShield, Shield stacking headers for Arduino, Base for Ultrasonic Sensor***	Ebay-internet	$ 319.39	$ 497.92
4	**3D Printer and plastic filament**	Dell-internet	$ 3,743.21	$ 3,157.19
5	**Laptops**	Local vendor	$ 3,927.20	$ 4,600.68
6	**Soldering and hot air gun station, Solder wire, Wire stripper, AA Alkaline Batteries, Hot Glue Gun, Hot Glue Sticks, Screwdriver Set***	Local vendor/Internet	$ 607.82	$ 811.77
7	**Decorating items, Poster paper, Pencils, erasers, notebooks, Assorted Markers, Certificate Awards**	Local vendor	$ 275.00	$ 717.68
8	**T-shirts and banner**	Local vendor	$ 850.00	$ 780.00
9	**Snacks**	Local vendor	$ 360.00	$ 360.00
10	**Contingency**	Local vendor	$ 649.35	$ 488.98
11	**Institutional Overhead**	Local vendor	$ 1,363.64	$ 1,500.00
		Total	**$ 15,000.00**	**$ 14,915.86**
		Balance**	**$ 84.14**	

*Several items were grouped together to reduce shipping and handling costs with Global Web Shopping, a local company that provides this service from Miami to Panama

**So far there is a remaining balance of $84.14. However, this balance might be used if the last purchase ends up being more expensive than the amount listed on the quotation. The last order for internet shopping was placed on 10/03/17 because these items were not available at the budgeted price when the rest of the items were purchased. The real cost of this purchase depends on customs duty and weight once the products arrive to Panama. The pending items did not affect at all the development of the program.

5. Project duration, tasks, and schedule.

Material Preparation

- **August 1st, 2016-March 31st, 2017:** Instructions manuals were prepared for students and instructors with all the sessions held at the university. Instructions manuals have been attached on a separate folder.
- **March 1st – October 3rd, 2017:** Purchase of materials were done locally and through the internet.

6. Results

Results have been divided between program activities and survey results. Program activities display all activities for the six sessions of the program. Survey results highlight the strengths of the program and make an analysis on possible reasons why STEM areas are still not chosen by some students.

a. Program Activities

- **June 15th, 2017:** Session 1 of the STEM Beyond the Borders program. Students assembled the structure of their robotic cars. A survey was conducted at the beginning of the program to measure student's perception toward science, technology, engineering and mathematics. Fig. 2 shows students taking the initial survey. Fig. 3 shows a group of students assembling their robots.

Fig. 2. Students taking initial survey during the first session of the program

Fig. 3. Students assembling their structures during the first session of the program

- **June 16th, 2017:** Session 2 of the STEM Beyond the Borders program. Students learned how to program the Arduino boards starting from a simple example to light on an LED. Then, they were able to develop a program to control the motors of their robotic cars with the help of the Adafruit Motorshields. Fig. 4 shows a group of students controlling the ON/OFF time of an LED with an Arduino Mega board. They were being assisted by freshmen/sophomore students from the electrical engineering department at the Technological University of Panama.

Fig. 4. Students learning how to control an LED during the second session of the program. They were assisted by volunteer students from the electrical engineering department at Technological University of Panama.

- **June 23rd, 2017:** Session 3 of the STEM Beyond the Borders program. Students learned how to read distance with an ultrasonic sensor and they used that information to control the servo motor and the motor-wheels. A survey couldn't be conducted on the third week of the program to evaluate the progress to date due to lack of time during the session. In this session students faced problems to control the DC motors that were solved by soldering ceramic capacitors to reduce feedback noise into the Arduino boards. Fig. 5 shows a group of students building a tower out of Styrofoam cups to have different distances at different levels. Fig. 6 shows a group of students reading distance with an ultrasonic sensor. Readings using an ultrasonic sensor were compared to readings done with a ruler.

Fig. 5. Students building a tower out of Styrofoam cups during the third session of the program.

Fig. 6. Students learning how to measure distance with an ultrasonic sensor during the third session of the program. They built a tower to have different measures when they moved the ultrasonic sensor straight up.

- **June 30th, 2017:** Session 4 of the STEM Beyond the Borders program. Students had a 3D modelling session to learn how to design 3 dimensional structures. They designed and 3D printed a baseball hat to be integrated with their robotic cars. Fig. 7 shows the MakerBot Replicator + 3D printing the baseball hat designed by students during this session. Fig. 8 shows a group of students showcasing the final result of the modelling session.

Fig. 7. Baseball hat being 3D printed during the fourth session of the program.

Fig. 8. Students showcasing their baseball hat designed during the fourth session of the program.

- **July 7th, 2017:** Session 5 of the STEM Beyond the Borders program. Students prepared a poster and set up their robotic cars to prepare for the competition. During this session students, volunteers and teachers received a t-shirt of the program. Fig 9 shows the poster done by the SMARTBOTS team. Fig 10 shows the poster done by the TECNOGIRLS team. Fig. 10 shows Dr. Victoria Serrano with the group of teachers who attended each session of the program.

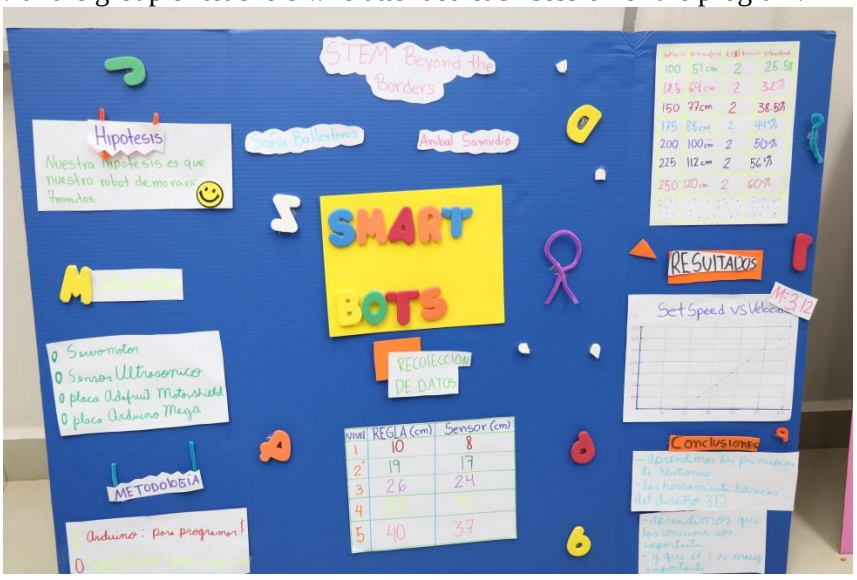

Fig. 9. Poster by the SMARTBOTS team during the fifth session of the program.

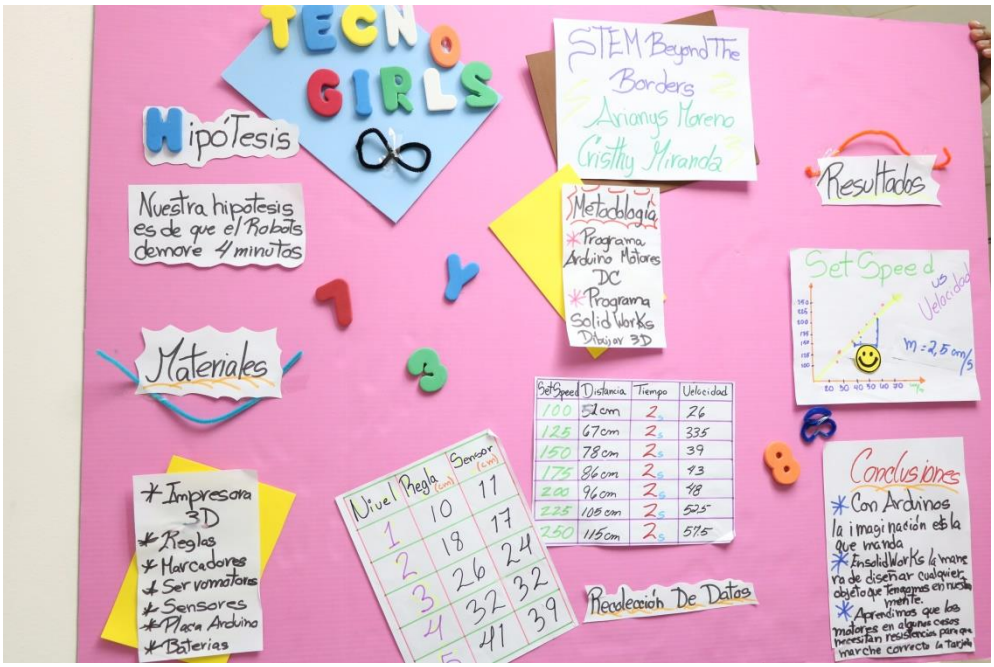

Fig. 10. Poster by the TECNOGIRLS team during the fifth session of the program.

Fig. 11. Dr. Victoria Serrano with group of teachers during the fifth session of the program.

- **July 14th, 2017:** Session 6 of the STEM Beyond the Borders program. Students presented their posters and participated in an obstacle avoidance competition. A survey was conducted at the end of the program to evaluate how the program helped shape student's interests toward science, technology, mathematics and engineering. Results from the program's surveys are presented in the survey results section. Fig. 12 and 13 show groups of students presenting their poster from Felix Olivares Contreras High School and Beatriz Miranda de Cabal High School, respectively. Fig. 14 shows the start of the obstacle avoidance competition. Finally, Fig. 15 displays one of the robots reaching the finish line at the competition.

Fig. 12. Students from Felix Olivares Contreras High School present their poster during the sixth session of the program.

Fig. 13. Students from Beatriz Miranda de Cabal High School present their poster during the sixth session of the program.

Fig. 14. Students starting their obstacle avoidance competition during the sixth session of the program.

Fig. 15. One of the robots at the obstacle avoidance competition during the sixth session of the program.

b. Survey Results

The following results show students' responses to a survey applied on the first and last session of the program. The survey is attached at the end of the "instruction manual for instructors". The demographics correspond to a total of 18 students, 11 female and 7 males. Six students came from public schools while twelve were studying at private schools. Students were asked to respond to each question and were given five different answers: Complete Disagree (CD), Disagree (D), Neutral (N), Agree (A) and Completely Agree (CA). The "Blue" bar depicts the percentage of responses before the program started while the "Red" bar describes the answers after the program took place. A total of 38 questions related to the perception of Science, Technology, Engineering and Mathematics were asked to each student.

Fig. 16 shows how the result changed when students were asked if engineers play an important role at society improvement. At the beginning less than 60% of students completely agreed with that statement and this result increased to more than 75% at the end of the program. Sometimes students have a bad perception on what engineers do, but the interaction between high school students and university students and professors help them change the erroneous perception about how important their role is in society.

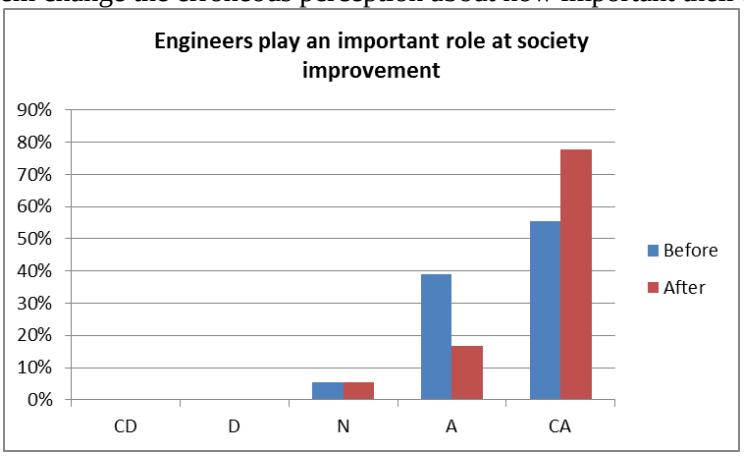

Fig. 16. Survey results when students were asked if engineers play an important role at society improvement.

In Fig. 17 the result for the question if engineers are innovative is presented. Although there was an increase of more than 5% for the result "Disagree", there was a substantial reduction in the response "Agree" to "Completely Agree" at the end of the program. One of the reasons for that could be that high schools students were exposed to some problems during the program that they had to solve using their imagination. That way they figured out that engineers are innovative when they have to solve problems.

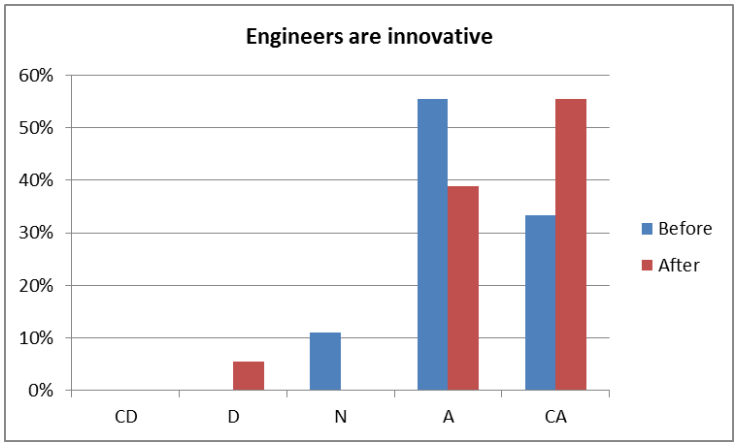

Fig. 17. Survey results when students were asked if engineers are innovative

Fig. 18 shows the results for when students were asked if math is fun. Although there was a raise in the number of students who "Agreed" and "Completely Agreed" with this statement at the end of the program, there was also a raise who "Disagreed" or "Completely Disagreed" with that. And that may be still one of the reasons why students don't go to engineering. They see math as an obstacle instead of something to have fun with. This is also reflected in Fig. 19 where a considerable number of students would not like a job that uses math. However, not everything is negative since in the same figure there is also a raise in the number of students who "Completely agreed" to have a job that uses math. This gives us a path to keep working on this type of projects to change the perception of students about Mathematics in the future.

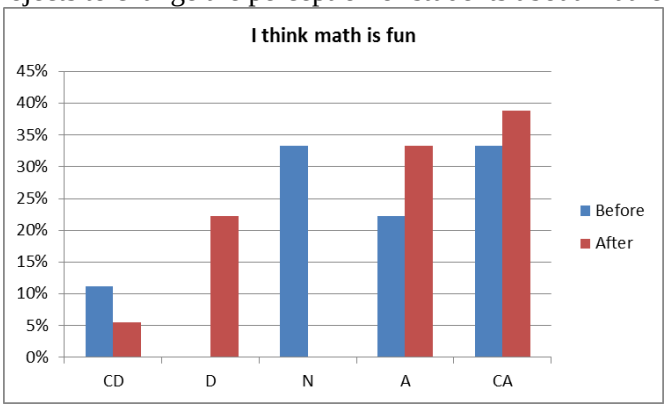

Fig. 18. Survey results when students were asked if math is fun

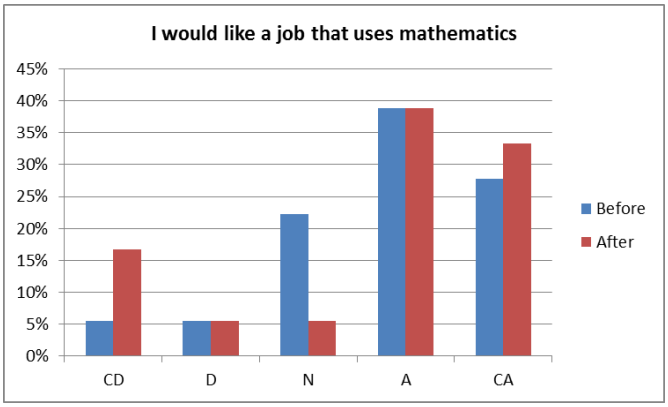

Fig. 19. Survey results when students were asked if they would like a job that uses mathematics

Fig. 20 confirms our interpretation of the survey results about how students still see math in high school. Here they were asked to answer if they thought they could do well in math classes at the university. Although there was a raise in the number of students who "Agreed" with this statement, there was also a little increment in people who "Disagreed" with that. Thus, despite the fact that they think that the role that engineers play is important and engineers are innovative, they still see math as something complicated to deal with.

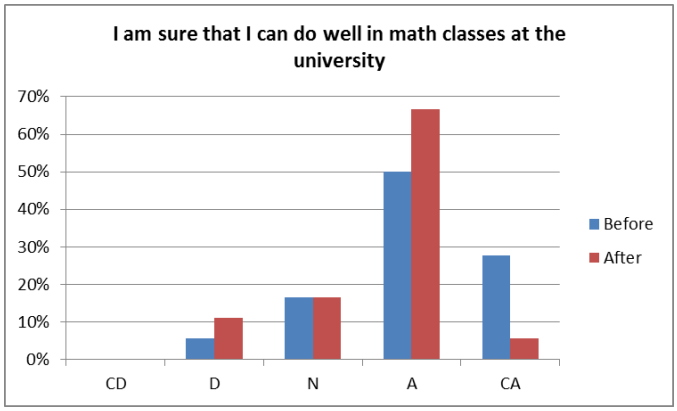

Fig. 20. Survey results when students were asked if they are sure that they can do well in math classes at the university

In Fig. 21, students were asked if studying engineering is worth it. Results show a positive increment in responses since most of them were from being “Neutral” and “Agree” with the statement to “Completely Agree”. This answer provides a meaningful insight because it shows that despite that engineering may be a difficult major to study for the amount of math involved in classes, students think that is worth it to go for it.

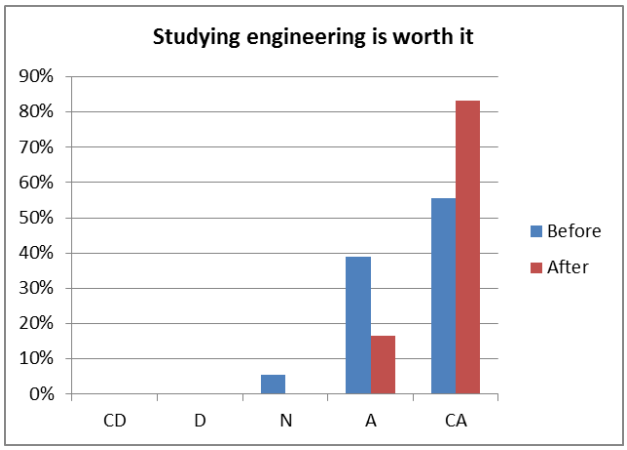

Fig. 21. Survey results when students were asked if studying engineering is worth it

The rest of the results show a significant improvement in technical skills developed during the program. Fig. 22 show the results when students were asked if they knew how to use the Arduino boards. Only a small percentage of students knew it before the program started, but at the end of the program all of them knew how to use it (Agree and Completely Agree).

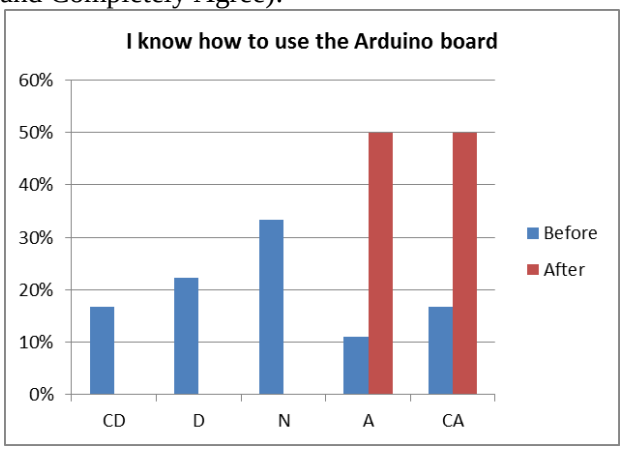

Fig. 22. Survey results when students were asked if they know how to use the Arduino board

Similarly, in Fig. 23 students showed a remarkable increase in “Agree” and “Completely Agree” responses when they were asked if they knew how to control a robot. Some of them were positive to that question at the beginning of the program due to the fact that some participating students belong to robotic clubs at their schools.

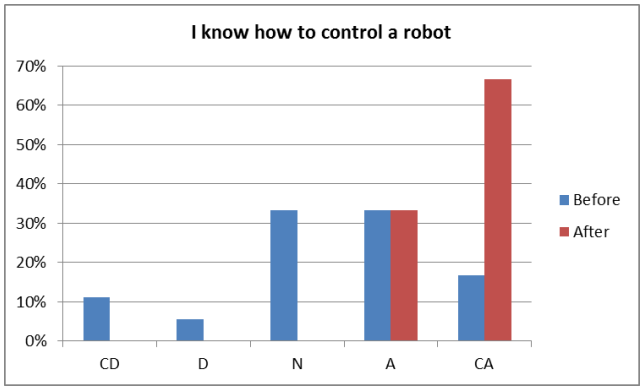

Fig. 23. Survey results when students were asked if they know how to control a robot

Another technical question was if students knew how to calculate velocity as it is shown in Fig. 24. Again a significant increment of positive responses was obtained at the end of the program. This is relevant because students can relate to everyday events mathematical concepts that they learn theoretically in their regular classes.

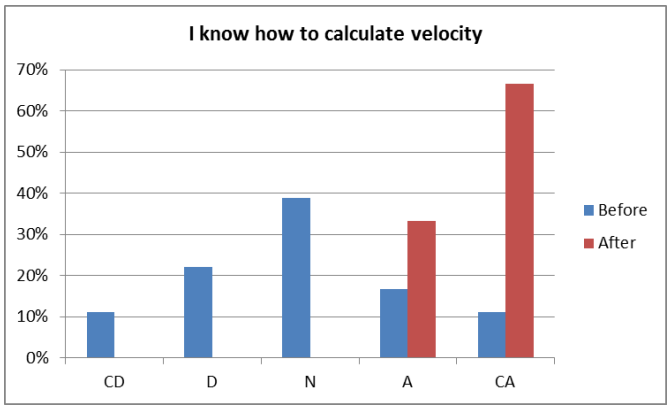

Fig. 24. Survey results when students were asked if they know how to calculate velocity

A similar behavior happened in Fig. 25 where students were asked if they knew how to plot data. Most of them did not know how to at the beginning of the program and most of them acquired that knowledge at the end.

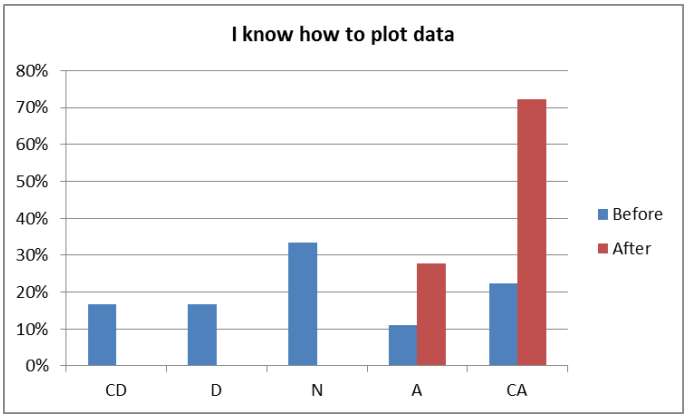

Fig. 25. Survey results when students were asked if they know how to plot data

Finally, the study asked if students were planning to study a career in science, technology, engineering and mathematics in Fig. 26. Although not all of them agreed, more than 90% are considering it as an option which provides relevant information that this type of projects may influence in students' careers decisions. However, a longer and sustained project is needed to obtain relevant data for this analysis.

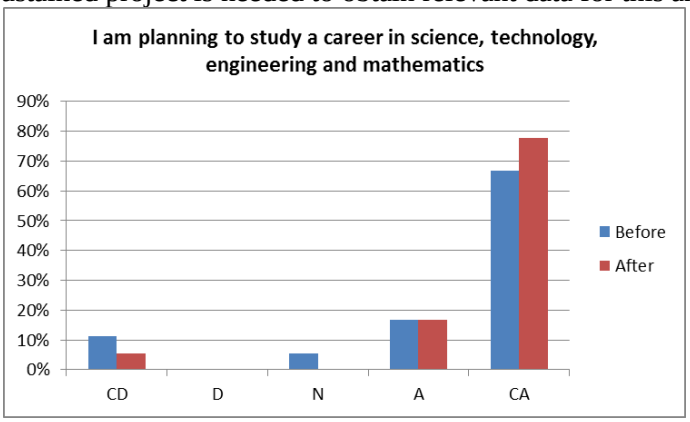

Fig. 26. Survey results when students were asked if they are planning to study a career in science, technology, engineering and mathematics

Students were also asked to respond qualitative questions such as the most difficult and easiest part of the program, what they liked the most and the least, and what they would have liked to learn. Most of them agreed that one of the most difficult parts was programming. This was somehow expected because Arduino is a non-graphical type of program. Instead it uses a myriad of commands that should follow a specific syntax to be able to work. The easiest part varied from assembling the structure, to turn the LED ON/OFF and learning the Arduino capabilities, among others.
On the other hand, students responded a series of answers for what they liked the most from the program such as: assembling, 3D design, learning something new about Arduino and get together and meet new people. When the survey asked what they didn't like the least, many agreed that the program was too short. For what they would have liked to learn, they responded things like: learning more complex programming commands, using different sensors and more classes in 3D modeling. Therefore, this leaves the possibility of planning future programs like this one.

7. Sustainability Plan

In July, 2017 some of the materials were donated to participating schools as part of the sustainability plan. Two of the high schools have already used them to participate in scientific fairs and robotic competitions. Fig. 27 displays students from Adventista Bilingue de David High School showcasing the mobile robot from the outreach program at a scientific fair organized by the Ministry of Education. Fig. 28 shows the winning team for the educative innovation competition organized by Fundacion Telefonica awarded to Beatriz Miranda de Cabal High School. This is one of the schools participating in the STEM Beyond the Borders program. Additionally, other schools will be using the Arduino boards with other applications to participate in the Robocup competition where the best teams are selected to represent the country internationally.

Fig. 27. Students from Adventista Bilingue de David High School showcasing their Arduino-based robot at a scientific fair.

Fig. 28. Students from Beatriz Miranda de Cabal High School winning the first place at the educative innovation competition where they used the equipment donated to their school to develop an innovative project.

The rest of the equipment remains at the Technological University of Panama for the development of future outreach programs and other activities. Part of the equipment was already used to promote research among undergraduate students. Table 2 shows a number of teams that used Arduino boards to develop their research projects:

Table 2. Undergraduate students doing research with Arduino Mega boards.

Students	Name of the Project	Type of Project	Participation Start/Finish	Participation at the Undergraduate Research Initiative?	Results
Romario Pitti, Einar Pérez, Carlos Aguilar	Automated Residential Electricity Consumption Control	Applied research	March-October, 2017	Yes	Selected as finalists from the Regional Center of Chiriqui
Douglas Miranda, Michael Saavedra, Jose Laydera	Hydroponic Analysis Of Lettuces	Applied research	March-July, 2017	Yes	
Carlos Muñoz, Stalyn De Gracia,César Quiel	Residential Automation with Arduino Technology Focused on Energy Saving	Applied research	March-July, 2017	No	
Abel González, Edibert De León, Oliver Guerra	DC Motor Synchronization	Applied research	March-July, 2017	No	
Sugelys Morales, Joel Núñez, Carlos Quiróz	Water Flow Monitoring and Control with Arduino Technology	Applied research	March-July, 2017	Yes	
José E. Muñoz, Emanuel Parrales, Leonardo Lara	Plastic identification and classification using resonance frequency	Applied research	March-July, 2017	No	

Fig. 29a and 29b show the groups of students who participated at the Undergraduate Research Initiative, but were not selected as finalist. Their projects were: Hydroponic Analysis Of Lettuces, and Water Flow Monitoring and Control with Arduino Technology, respectively. Fig. 30a and 30b depicts the finalist participating at the regional competition and the National Undergraduate Research Initiative (NURI), respectively. The NURI took place as part of the 6th Engineering, Science and Technology International Conference in Panama City. This activity gives students the opportunity to publish their papers at the Journal of Undergraduate Research in Panama.

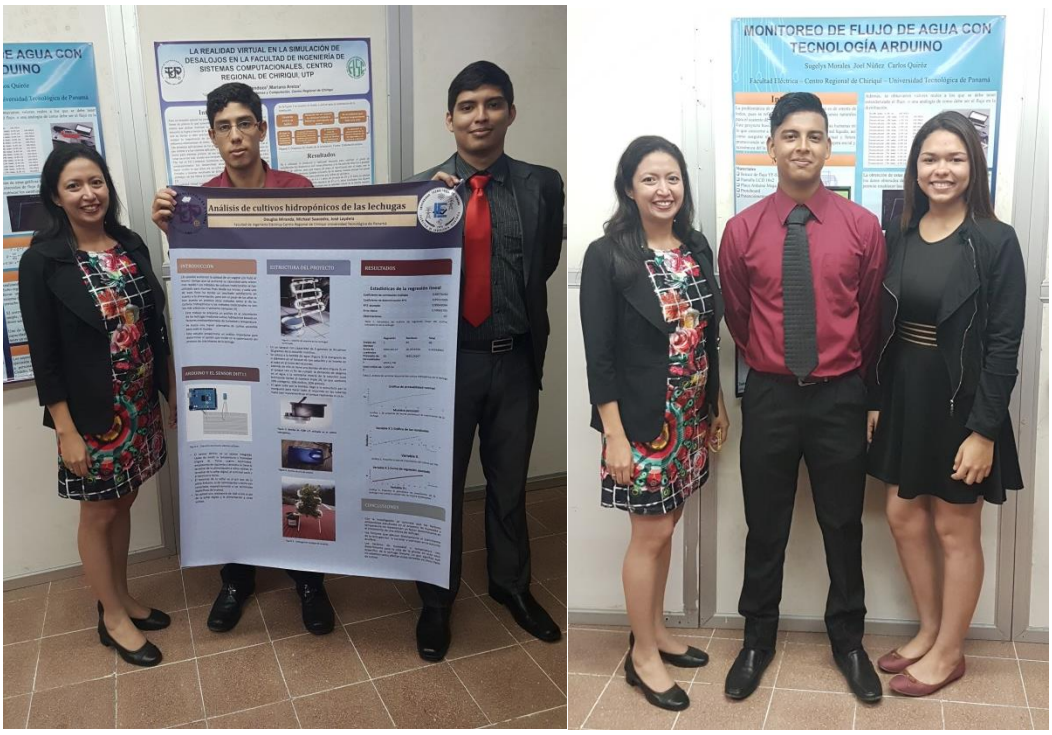

Fig. 29a and 29b. Students participating at the Regional Undergraduate Research Initiative. (a) Project Name: Hydroponic Analysis Of Lettuces, (b) Project Name: Water Flow Monitoring and Control with Arduino Technology

Fig. 30a and 30b. Students selected to represent the Regional Center of Chiriqui at the National Undergraduate Research Initiative with the project Automated Residential Electricity Consumption Control. (a) Regional Competition. (b) National Competition.

8. Conference Presentation

An abstract was submitted in September and pre-accepted for possible publication at the II IEEE World Engineering Education Conference – EDUNINE2018, which will be held in Buenos Aires, Argentina on March 11th to 14th, 2018.