Getting Ready for Professional Education: The Research Experience of a Middle School Student in Design of a Smart Bed

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Abstract

The Pre-college Summer Scholars (PSS) program is a 10-week program designed to give secondary students the opportunity to work on hands-on engineering projects. The students completed various projects throughout the summer and learned about science, math, engineering, and technology (STEM) while being assisted by secondary teachers and professors. During the program, they learned many things such as what Arduinos and Raspberry Pi 3s are and how they can be used and what the Internet of Things is and what it can be used for. They also learned about websites, like IEEE Xplore and Tinkercad. A major project that the students worked on was to duplicate how the Internet of Things is used in the building assigned to them. For example, a hospital uses IoT for Smart beds. This program extends into the school year, where they will assist their respective teachers and continue to learn more about the STEM field. At the end of the school year, the students will be expected to go to a conference and present a paper that they have written about their experiences and achievements during the program. By giving them hands-on experience and good mentors, this program has opened many great opportunities and taught them several things that they will continue to use throughout their future.

Keywords — RET, Internet of Things, Cloud, STEM, PISA, PSS

I. Introduction

The 10-week Pre-college Summer Scholars (PSS) is a program designed for students in secondary school. It is founded by the National Science Foundation (NSF)[1] and established for the purpose of mentoring students in hands-on projects while teaching them important information about Science, Technology, Engineering, and Math (STEM). The program is effective due to the atmosphere it takes place in, where everyone is kind and happy to assist when someone needs help. For things that are already known, the program helps strengthen the skills. The major project that the students worked on during the program was the use of IoT in a certain department. For example, a Hospital that uses IoT for smart beds that are able to take patient information with sensors and determine if the patient needs anything . Another example is in banks, where a use of IoT is in cameras that detect motion after closing hours. The cameras help detect when there are intruders in the bank and do it in close-to-real-time. These are great projects to help gain knowledge in the STEM fields. The students work on problem-solving for much of their projects.

The STEM knowledge they gain is a valuable aspect as there are a rising number of STEM jobs that are available with a rising salary. As of May 2015, there were nearly 8.6 Million open STEM jobs, of which 45% were computer occupations, 19% engineering, and 36% other STEM occupations. The national average wage for STEM jobs was $87, 570 almost double the national average wage for non-stem jobs, $45, 700. 93 out of 100 STEM jobs had salaries above the national average. Between May 2009 and May 2015, employment in STEM jobs grew by 10.5%, or 817,260 jobs, while non-STEM employment only grew by 5.2% [2].

II. Pre-College Summer Scholars Program

To join this program, the students first had to apply for PSS by sending a page-long statement about why they wanted to join and a recommendation letter. This program extends into the school year where students will assist their teacher and learn as much as they can. During the summer portion, the students helped the mentors with tasks, while learning all that they could about STEM. At the end of the school year, the students are expected to attend a conference, where they will present their work and what they learned. PSS is also an excellent way for students to get closer to their teacher, as they need a recommendation from them and will work with them for the length of the school year.

There are other programs like this, including the Electrical Engineering With Raspberry Pi one-week camp[3] that takes place in many places around the USA and Canada, and the Internet of Things (IoT) Resident Hackathon Camp in Clearly University[4]. There are even STEM schools[5], where the main priority is teaching the students 4 things, science, technology, engineering, and math. According to the Program for International Student Assessment (PISA)[11] in 2015, out of 71 countries the USA placed 38th in science and 24th in math. The test determined that US students were average in science and reading, but below average in math. The US did better and worse in all STEM fields, as shown in figure 1. This information shows that teaching about the STEM field will help not only the person, but the country as a whole.

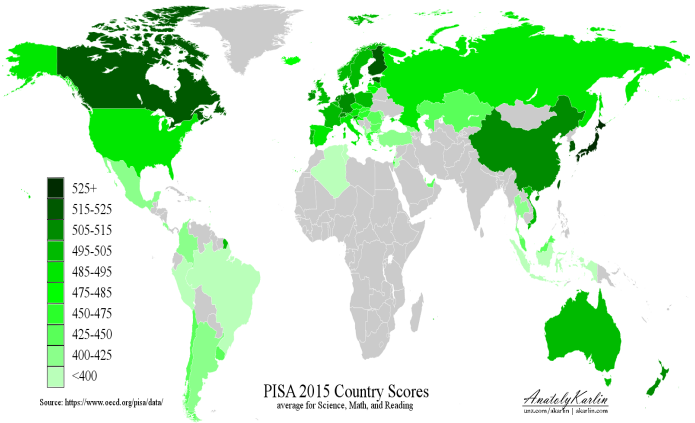

Figure 1: Average country PISA scores

This program makes students aware of how much engineering and IoT is used around them. It also makes them appreciate how far humans have come and how futuristic the world currently is.

The specific Raspberry Pi we used was the Raspberry Pi 3 and the Arduino was the Arduino Feather Huzzah ESP8266. The Huzzah has 15 digital pins which can be used for Input, Output or Pull Up, pin '16' can be used for Input, Output or Pull Down. The Huzzah has a built-in USB and battery charging and a 4MB flash memory. This has a built-in WiFi and hence no connection was necessary. Secondary school students were given the Arduino, a walkthrough paper, a partner, and a graduate student for help. Raspberry Pi's can operate on many open sources like Linux software such as Noobs and Raspbian. The Raspberry Pi 3's that we used had 40 pins total, 4 USB 2 ports, HDMI port, microSD slot, micro USB power supply, and a Quad Core 1.2 GHz Broadcom BCM 1837 64 bit CPU [6].

With a lot of help, the students were able to understand how a loop, a library, and a General Purpose Input Output (GPIO) pin worked. They learned this by doing labs, tutorials, and listening to many graduate student explanations. Some labs covered in the program were wiring up and typing in the programs for an ultrasonic sensor, a motion sensor, and a simple LED light. One particular lab covered was an ultrasonic sensor hooked to an Arduino. If an object was within a certain distance of the sensor, then the light would turn on. A similar lab covered the same thing but with a motion sensor instead of an ultrasonic sensor. In instances like those, the C++ language they were using to program the sensors needed an "if-else" statement. This is where "if" a condition was met then action would occur, otherwise, something "else" would occur. To continually run that program there had to be a "while" loop meaning while something was true then it would repeatedly run all of the programs in the loop. The schematic of Figure 2 shows how they wired an ultrasonic with LED to an Arduino.

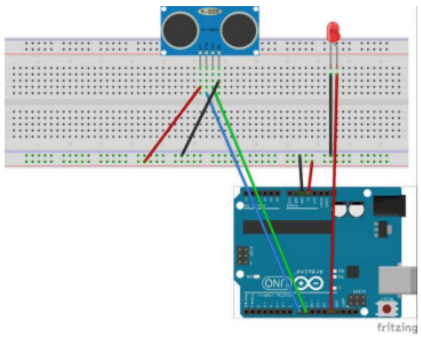

Figure 2: Connections to operate an Ultrasonic sensor and an LED

The students were asked to work on multiple sensors and motors controlled by Arduino Feather Huzzah ESP8266 using ThingSpeak to test and collect data. The main purpose of doing this was to make the students learn how ThingSpeak works and to determine how easy is it for younger students to work on. The good part of ThingSpeak was that it was especially user-friendly and used normal English. The goal of the project was to collect all the data from the

sensors and send the collected data to a central database server or the cloud. Figure 3 illustrates the data collected through sensors in the form of graphs.

During the learning process, the professors started to educate the secondary students about electricity and magnets with their properties. They worked with bulb circuits and looked at the flow and splitting of energy. They learned things like how much voltage is needed to get a round or long bulb to light up, and why bulbs get shorted out. Another thing they learned was about Lenz's Law, which explains why a magnet falls much slower when dropped through a copper tube than it would fall if it was dropped elsewhere. A magnet falling through a copper tube conducts a current, which, according to Lenz's Law, creates a magnetic field in the copper tube. This process is shown in figure 4.

The students took this project a step further and decided to try dropping the magnets through an 18-foot-pole. They first tested the speed of the magnets going through a 2 foot and a 1-foot tube. Using those numbers, the tried to predict how long the magnets would take to go down the 18-foot pole. They tested dropping different amounts of magnets through the long pole, 1 magnet, 2 magnets, etc… The discovery was that the more magnets put through the pole, the less time taken for the magnets to reach the bottom. When dropping 6 magnets through the long pole, the students timed it. The 6 magnets took 40.5 seconds, which was less than the 45 seconds the students had predicted it would take to reach the bottom.

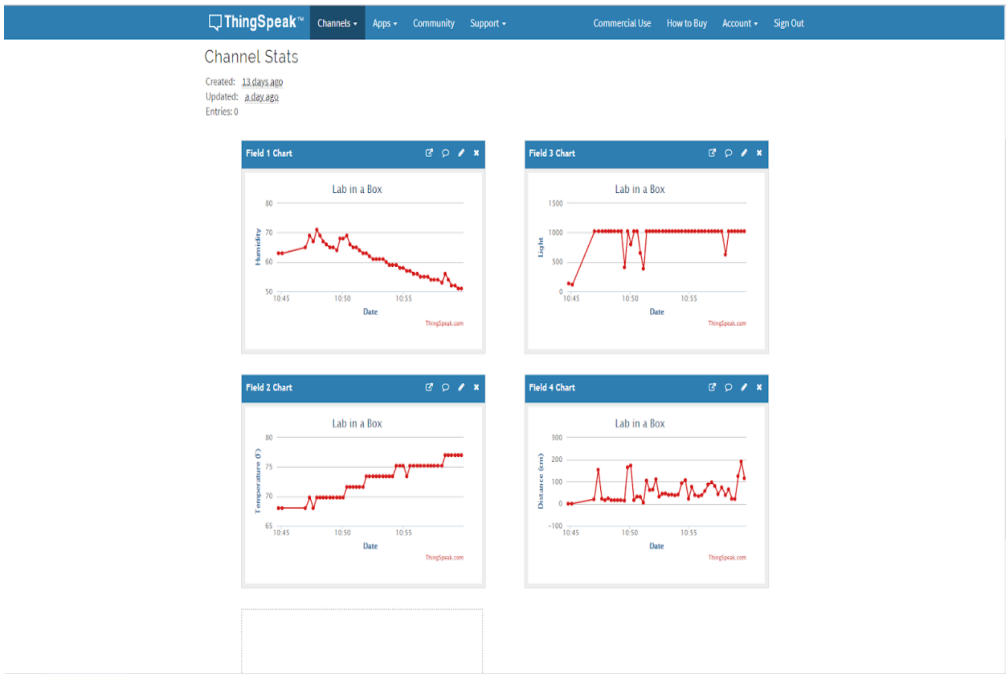

Figure 3: Data collected from the sensors and stored in the cloud

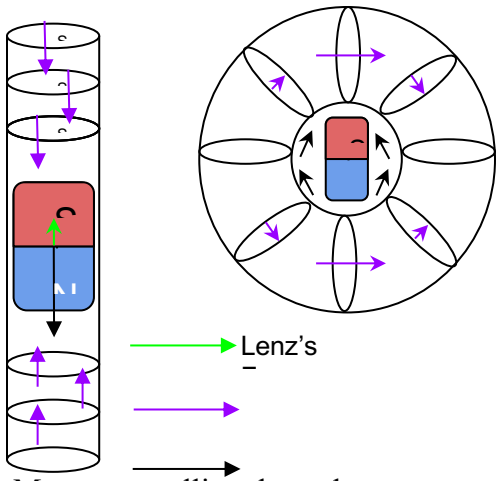

Figure 4: Magnet travelling through a copper rod

IV. Technical Project

After learning about electricity and magnets and getting a better idea of how IoT works, the students were tasked with duplicating the usage of IoT in a department, like a Hospital. The students used the website IEEE Xplore[7] to look for research papers that would suit their needs. IEEE Xplore is a great website to search for research papers because it has options that allow people to set the publish dates and the topic of the papers that they view.

After finding the papers, they had to find out why it was used, if it was helping someone or something, and how it was helping. The Smart Medical bed is used to more comfort to the patient and decrease the workload on nurses. The Bed uses sensors to take medical information from the patients and send it to the nurse and/or doctor. It also allows the patient themselves to see their records, medication, and be able to adjust the bed to their own needs[9]. Another great effect of the smart bed is how the bed does all the things it's programmed to do without bothering the patient.

IoT is used in hospitals for smart beds. The IoT allows the bed to take information and send it directly to the patient or nurse. Hospital beds are usually 3-part beds, and the smart beds that one of the students created had to be too. After discovering the papers, they had to find out why it was used, if it was helping someone or something, how it was helping. The Smart Medical bed is used to more comfort to the patient and decrease the workload on nurses. The Bed uses sensors to take medical information from the patients and send it to the nurse and/or doctor. It also allows the patient themselves to see their records, medication, and be able to adjust the bed to their own needs[8]. Another great effect of the smart bed is how the bed does all the things it's programmed to do without bothering the patient [9]. The bed was not going to be life-size, instead, it would be a 3D printed mini version. The 3D design was going to be created on Tinkercad[10], a 3D design creating website.

After becoming conversant to the Arduino Language, the next step was to look for projects that closely matched theirs. Gathering research papers and reading more about IoT that can be used for our daily needs was the first step. The next thing in mind for one of the students was to create ideas on how to make a Smart Hospital Bed. Utilizing the information collected from the literature review, the main goal was to transmit information of the patient on the bed to the nurse in order to minimize the work of the nurse to go to every patient to check whether they were all content. The authors of the papers that were viewed were able to figure out a clever plan where a smart technology collects all the information and sends it to the cloud where other smart technology devices can bring down the data to be used. After doing extensive research, the secondary school students joined professors, student teachers, and other teachers to experiment with ultrasonic sensors, Temperature and Humidity sensors, light sensors, etc.

The first challenge faced was to move the servo motor in perfect rotations that were required for the bed to pivot as needed. Doing this, the student had to thoroughly understand the Arduino code and how to make the necessary changes in the code for the servo motor to run perfectly as per the needs.

After storing the data, the next step was to pull the data from the cloud from another source and to access it. This part was a challenge. When one of students started to work on how to retrieve the data from the cloud, the other student parallelly started working on TinkerCAD for 3D printing and assembling of the bed. Hospital beds are usually 3-part beds, and the smart beds had to be too.

The first challenge in creating this bed was having a 3 parts printed, each part had to be individual and able to move side to side and tilt up and down. The first draft was soon created, shown in figure 5. The cubes and spheres on the ends of each part were made so the bed could freely turn side to side and stay attached. When the 3D prints came in, a problem was noticed. The connectors were not strong enough to withstand the weight of its connecting parts. The solution to this problem was to make the connector slightly big enough making the hole into a perfect shape so it would connect each other perfectly. That allowed the parts to move up and down, instead of side to side.

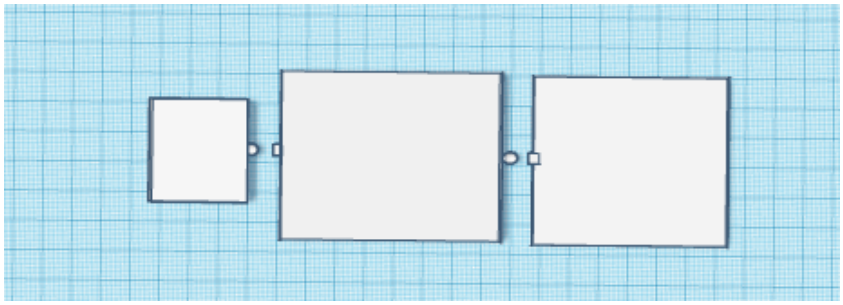

Fig 5: 3-part-bed first design.

The next challenge was creating a way for the parts to move on their own. The thought up a solution for this was a servo motor. If they could find a way to attach the servo motor, to the bed, it would be a moving part bed, which they had intended for it to be. After spending some time exploring different ways to solve this, the student came up with another design, shown in figures 6 and 7.

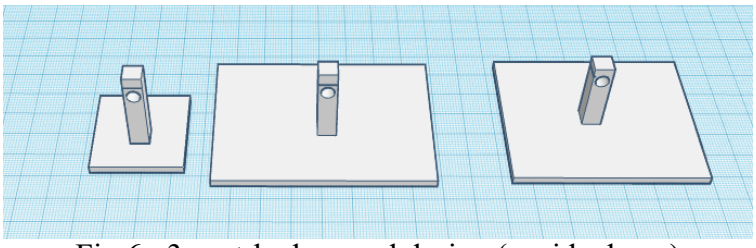

Fig 6 : 3-part-bed second design (upside down)

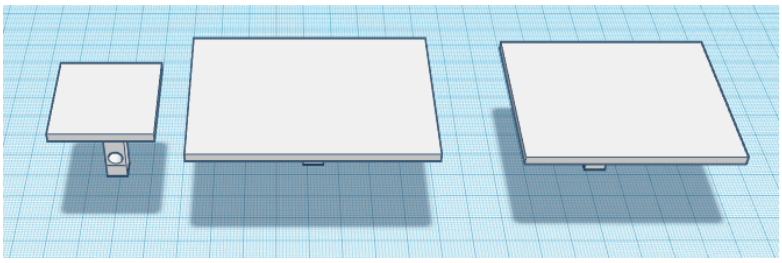

Fig 7: 3-part-bed second design

The servo motor was the ideal choice because of how the movement and angles of is are adjustable and controllable. The servo motor was connected to an Arduino Uno, shown in figure 8. The top of the servo motor would turn underneath the bed and push it to the angle that is declared in the code that was set up for the Arduino. This new design allowed for the servo motor to connect directly to the bed itself through the mini holes at the bottom of the bed stand. Instead of pushing the parts, it would be directly connected to the parts of the bed and the Arduino.

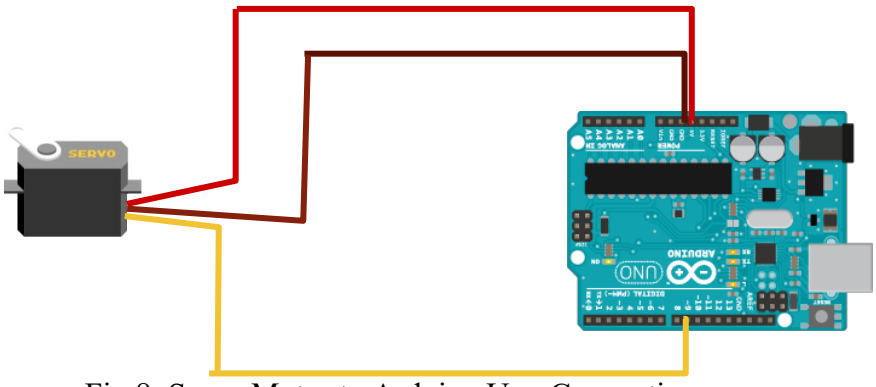

Fig 8: Servo Motor to Arduino Uno Connection

V. Results

All of the projects were educational and fun. The students got to do things like 3D Printing and learning the amazing effects of Lenz's Law. They also got to learn how to connect and set up Raspberry Pi 3 and an Arduino IDE to a computer, and how to code both. During the beginning of the program, the students hardly knew anything about the functions of an Arduino, a breadboard, or even what the Cloud was. The goal of this program was that by the end of the 10 weeks the students would know more about these things than they did before they started. Observing their achievements, these goals were reached, although the project was not completed, the students had worked hard and learned a lot from what they had done. The plans of the 10 weeks they were working is shown in Figure 9.

Week 1-2	Learned about IoT, sensors, and literature review.
Week 3-4	Learned about the functions and usage of a Raspberry Pi 3, Lenz's Law, and bulb circuits. Made electromagnets, and learned about volume.
Week 5	Research about hospital smart bead and collecting all the necessary information through literature review.
Week 6	Exploring TinkerCAD for 3D drawing of the bed, and 3D printing
Week 7-8	Worked on how to run sensors through Arduino codes and inbuilt libraries. Working on calculations on movement of the med through motors.
Week 9-10	Leaned deep into programming languages and database servers. Finished the paper & cleaned the lab.

Figure 9: Schedule of tasks during the program.

VI. Conclusion

The PSS program is a great program in teaching pre-college students about STEM. These students have been able to do many hands-on projects and learn about IoT. This will help them in the future, where they might get a STEM job. They have learned things from the simple functions of an Arduino and learning about sensors, to learning about reading and writing a research paper. This program allowed students to learn new skills and broaden their understanding of the whole STEM world.

RET participants of the group took home plentiful information about programming, microcontrollers, and simple electronics. Throughout the program, the engineering design process had been crucial. Some instances when using the process was during the wiring of the

Arduino and nothing worked or when testing out sensors on ThingSpeak. By learning more about these topics everyone in the program has grown more fascinated with STEM as a whole. When speaking to others in the program, everyone was in agreeance that it was a great experience to experience and everyone had a positive outlook on engineering.

Bibliography

1. Nsf.gov. (2019). *NSF - National Science Foundation*. [online] Available at: https://www.nsf.gov/ [Accessed 2 Mar. 2019].
2. Bls.gov. (2019). *U.S. Bureau of Labor Statistics*. [online] Available at: https://www.bls.gov/ [Accessed 2 Mar. 2019].
3. Digital Media Academy. (2019). *Python & Electrical Engineering Class - Teen Tech & STEM Summer Camp Program*. [online] Available at: https://www.digitalmediaacademy.org/robotics-and-engineering-camps/electrical-engineering-raspberry-pi/ [Accessed 2 Mar. 2019].
4. University, C. (2019). *Cleary University*. [online] Cleary University. Available at: https://www.cleary.edu [Accessed 2 Mar. 2019].
5. Stemschool.com. (2019). *STEM School - STEM Education Leads to Better Careers*. [online] Available at: https://www.stemschool.com [Accessed 2 Mar. 2019].
6. Raspberry Pi. (2019). *Raspberry Pi 3 Model B - Raspberry Pi*. [online] Available at: https://www.raspberrypi.org/products/raspberry-pi-3-model-b/ [Accessed 2 Mar. 2019].
7. Ieee.org. (2019). *IEEE - The world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.*. [online] Available at: http://www.ieee.org/ [Accessed 2 Mar. 2019].
8. Ieeexplore.ieee.org. (2019). *IEEE Xplore Digital Library*. [online] Available at: https://ieeexplore.ieee.org/Xplore/home.jsp [Accessed 2 Mar. 2019].
9. ResearchGate. (2019). *ResearchGate | Share and discover research*. [online] Available at: https://www.researchgate.net [Accessed 2 Mar. 2019].
10. Tinkercad. (2019). *Tinkercad | From mind to design in minutes*. [online] Available at: https://www.tinkercad.com/#/ [Accessed 2 Mar. 2019].
11. Oecd.org. (2019). *PISA - PISA*. [online] Available at: http://www.oecd.org/pisa/ [Accessed 2 Mar. 2019].