Experience of a High School Student in Engineering Design and Manufacturing through a Research Program

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Abstract— The summer engineering research program was an educational experience for both students and teachers of local school districts. The program taught participants about engineering and the practical uses of it in school buildings. As well as going beyond the surface of engineering and seeing how it can influence everyday life. During this 11-week course the secondary students learned things ranging from 3D printing to using the Raspberry Pi. Using the 3D printing, students were able to learn how to problem solve on their own and with using the Raspberry Pi students were able to learn how to code, collect data, and wire up complex circuits.

During the school year the students who participated in the program continued to work diligently on individualized tasks. Such tasks included taking the initiative to create personalized programs on the Raspberry Pi, work more in-depth on the aspects of engineering, and coming up with new labs to support the role of the engineering process in the robotics class. By the end of the program all of the participants gained a much deeper idea on what engineering is and the students will have a much better look as to how to continue down the path of an engineering career.

Key words- Summer RET, Tinkercad, Arduino

1. Introduction

This summer an amazing program called the Research Experience for Teachers (RET) was expanded to include secondary school students. This was a new change in the program, but it was a helpful change to students in the area that were looking into engineering careers. This program is an excellent way to dive into the ideas of engineering deeper than what is found in normal life. The RET program is the perfect opportunity for students interested in engineering, as it helps to show what they can expect in the future. This program also is a great way to get students more involved with their teachers because they need teacher recommendation letter needed to apply to the program, as well as the extensive work that students are expected to do with their teachers. Teachers who have already been through the program can help to better explain the program, as well as help students to apply. Due to the RET program, students will be able to take a step towards the future and have some fun along the way.

The RET program is such a tremendous help in teaching both secondary students and teachers new ideas and concepts of engineering, as well as helping solidify what they have already learned. As it is that there are very few ways one can learn about engineering at the high school level. The biggest thing about the program that makes for a good work environment and experience is how tightly knit everything is. Everybody is given little teams to work with, but it isn't that crazy of a thing to see the groups intermingling every day. Sometimes it was almost harder to tell who was with what group than it was to tell what the groups were actually doing

that day. That's one of the beautiful things about this program. Everyone may be separated on paper, but there isn't more than an inch of separation between groups and faculty members. On top of everyone being so friendly, there is always someone there to help participants when they need it. For example, many of the participants had been given a task to work on something that they had no clue how to run. However, with the help of the wonderful staff and grad students, participants are able to receive help and even instruction on how to use devices that they originally didn't know how to use. The whole program quickly turned from being a summer job to a summer experience for most participants. The program allows participants to work with people and equipment that they may have never expected to use. Moreover, participants never expected to end up feeling more of a part of a family unit rather than just working with co-workers. The program is well worth the experience and effort.

The RET program is very similar to programs ran at colleges all around the world. For example, it is run with a similar time frame and level of professionalism as the program at ECU in Australia (see Hinkley, Steven Secondary Students Research). This program, however, has done much more than simply teach about engineering through research. It has also helped to broaden participants' spectrums and show how

engineering could effectively be implemented into everyday teaching in classrooms. This concept was further expanded upon in the article "Inclusion by Design" (Dukes, Charles "Inclusion By design."). Due to this, the program has also helped participants to look for the engineering process in places they may not have expected it to be.

2. Projects

A. *Raspberry Pi 3*

Fig. 1: Raspberry Pi 3 Model B used in the RET research

The experiences as far as project go have been remarkably fun and educational. Some of the projects done range from 3D printing, to Arduinos, to working with Raspberry PI 3's. One of the more recent projects has been working with the Raspberry PI 3 (Deshmukh, "Raspberry Pi Technology."). The primary task has been learning how to use it. This involved the use of a four-pronged ultrasonic sensor, a DC motor, and coding using Python. While this may be a harder task to figure out, it is among one of the best tasks. The Raspberry Pi system offers a great educational opportunity. The Pi looks to be nothing more than a computer chip, but it can do so much more than what is expected of it. The Raspberry Pi is literally a small, fully programmable computer. The coolest part about it is how easy it is to use. Even though it isn't always straightforward, it still is very user-friendly, allowing a person to figure it out and use it properly in less than a week. For example, an easy code to make is for the old arcade game Pong, which has several tutorials on how to make it online using Python code. A large chunk of materials can be found online to help walk people through how to use a Raspberry Pi. That's the beauty of the Pi, so much of it is an online community helping to make it easier to understand that even as a beginner there are endless resources to help explain the functions of the Pi. However, when the online resources failed, participants of the RET program were able to turn

to the wonderful staff and students around them who were willing to help and walk participants through what to do. They would explain what to do along the way so as to allow participants to learn from their mistakes and experiences.

B. 3D Printing

Along with working with the Raspberry Pi, the participants worked on other projects. One of those projects was 3D printing. This is something that some participants already knew how to do, so it was much easier for them, though it still proved to be rather challenging. There was several prints made, some good and some bad, that were to be little gizmos and gadgets to use in everyday life. These designs were to be printed on two different 3D printers. One printer was the Cube Pro, which prints parts without using support. The other printer was the MakerBot printer; this printer is a much more accurate printer, as it does use support material as needed.

Using the capabilities of 3D printing can be greatly useful for the world, even if there are some draw-backs. 3D printing allows for much faster creations and testing of prototypes, as well as helping to cut down on money consumed to make a prototype. It also allows for the creation of mass producing items that otherwise would be too expensive to make. Even if 3D printing is still new to the world, it is just like the internet in the sense that it will someday change everyday life. (see THE IMPACT OF 3D PRINTING TECHNOLOGY)

The three separate designs in this project are a phone box called the "Think Tank," a can/jar opener called the "Easy Opener," and a mechanism to keep shoes tied called the "Untieable Knot." Each of these projects was rather simple designs but they were nevertheless rather complicated to make. Each project will be broken down into separate parts. This will give the ability to go more in depth with each of the projects. Such as what they are used for, the process went through to make them, and the issues in the prints.

The first project and probably the easiest to explain is the "Untieable Knot." The concept behind this little piece is to make a way to lace shoes that keep them from coming untied. The idea of making this came up because of a pair of boat shoes that don't want to stay tied very well. So the design was started with a rough sketch of what the project would look like.
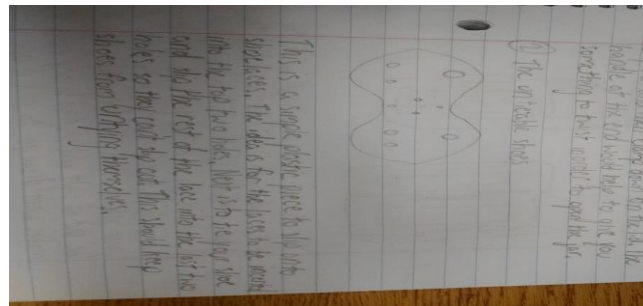

Fig. 2: Sketh from a notebook of what the "Untieable Knot" would look like

After coming up with a sketch, the next step was designing the part using a free online 3D modeling program called Tinkercad. The part wasn't hard to make on Tinkercad, but it was a little tedious. The thing that made it so tedious was its size, as it is only two inches long and seven-eighths of an inch wide. Its size proved to be an issue as Tinkercad gets harder to use when working on smaller parts and movements. After printing the part on the Cube Pro Printer the first issue was quickly discovered: There was no way a shoe lace would be able to fit through the holes. The problem was found quickly by going back to the 3D model. The holes for the laces were made too small due to an error in reading the dimensions and needed to be much bigger. However, there were no other issues in this print. The part has now been printed twice

on both printers, the MakerBot and Cube Pro, and the holes in both are still too small. So at the moment, it would seem that this project is destined to fail. However, there is still hope for this little project though, as it just needs a little more work. With some more work and time the "Untieable Knot" should be everything that it is hoped to be.
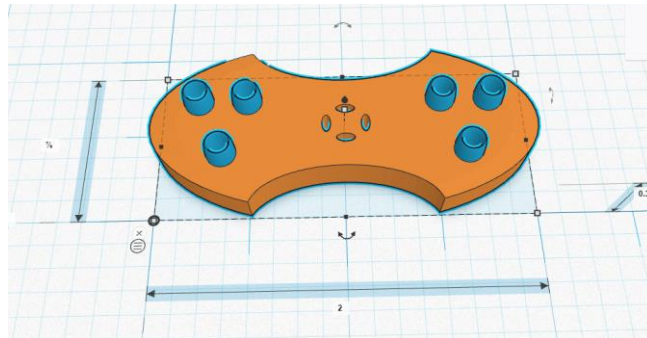

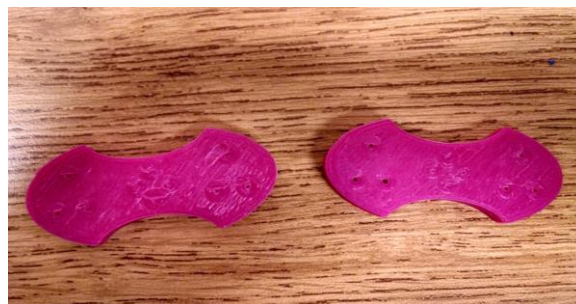Fig. 3: 3D model for the "Untieable Knot" made on Tinkercad

Fig. 4: First print of the "Untieable Knot" made on the Cube Pro

Fig 5: Second print of the "Untieable Knot" made on the MakerBot

The next design created is the "Easy Opener." It is a tool meant to help with opening up jar lids and potentially bottle caps. The idea behind it is to give the user a handle to turn rather than a lid to twist. The way it would clamp on to the lid is by a shaft with a claw on the end of it, which would then be pulled back into the handle by the force of a rubber band. This design started with nothing more than a simple sketch in a notebook, as all designs do. After sketching it, the next step was making the 3D design in Tinkercad.
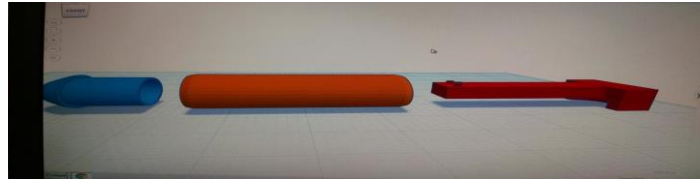
Fig 6: Originial 3D design of the "Easy Opener" made in Tinkercad

After seeing it printed on the Cube Pro, it was clear that there were some issues with it. The first issue was the shaft, which didn't print out flat like it should have been. The next big issue was the way the handle had a hole in it that wasn't supposed to be there. The final problem was the end cap that didn't print as one solid piece. Seeing these issues in the part, the part was taken back to have modifications made to the design in order to try and fix it. These fixes were made by making massive modifications to the design.

Fig. 7: First print of the "Easy Opener" made on the Cube Pro

These changes made it feel as though the design was being scrapped and started fresh. However, the new design seemed to be a much better outcome after seeing it printed. The part did, however, get printed on a different printer, which may have helped. This did lead to finding more success in the part, as both the handle and the shaft are now fine. Unfortunately, it appears that there are still some issues in the part, such as the cap for the back of it. So there still are issues that need to be fixed before making the final product. There is a good chance that this design, with a few more modifications of course, will turn out wonderfully.
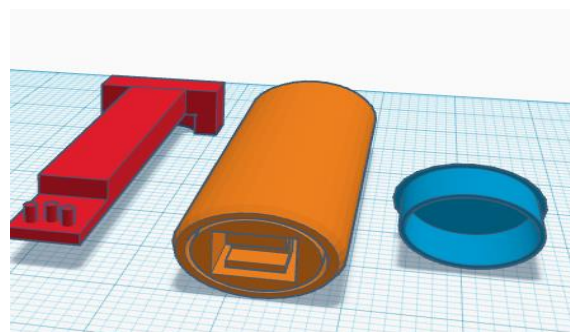

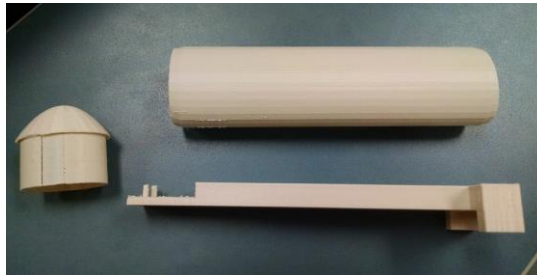Fig. 8: Second 3D design of the "Easy Opener" made in Tinkercad

Fig. 9: Second, fixed "Easy Opener" made on the MakerBot printer

The third design was the phone box called the "Think Tank." The purpose of the phone box is exactly as the name would suggest. It's a place to store a phone. However, it goes deeper than that. The idea is to put padding in one section of the box so that when a phone is in the box it won't make noise or light up, keeping it from distracting people. This box is meant to be used by students who are studying. The thought behind it is if students can hear or see their phone when trying to study or focus, then the phone will take away some of the focus. This prevents the ability to give full effort to the task the student is busy trying to complete. That is the concept of making a box to muffle the noise of a phone and keep it out of sight. The other half of the box was designed to be used for any other things that may be wanted to help study such as: flash cards, erasers, paper clips, etc. The project started the same way as all start. It was a sketch in a notebook. From there it was moved on to making a 3D model of the "Think Tank" in Tinkercad. There have been two prints of this part received. The "Think Tank" turned out to be a little bigger than expected but other than that there is only one complication with it.
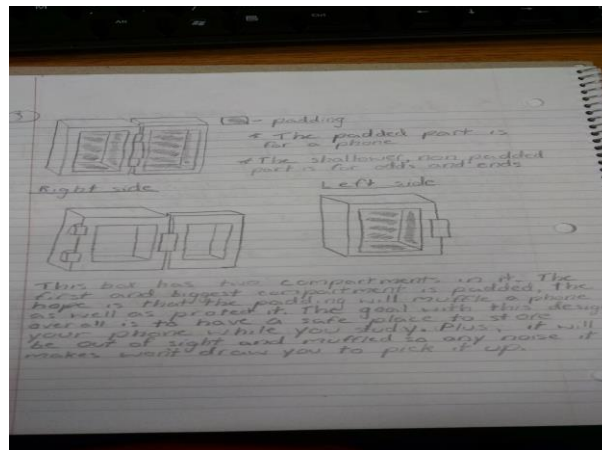

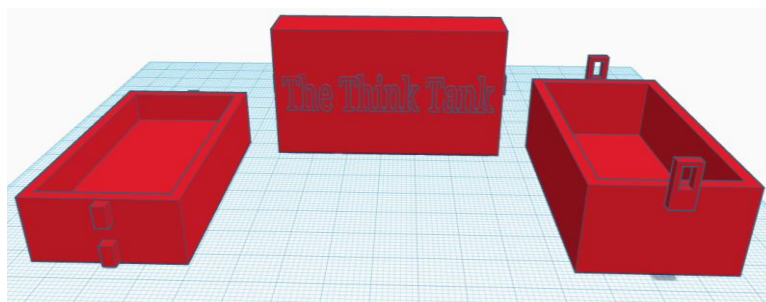Fig. 10: Sketch of the "Think Tank" drawn up in a notebook

Fig. 11: 3D model of the "Think Tank" made in Tinkercad

The "Think Tank" has clips on the side of it to keep it closed, but the square pegs that the clips hook to ended up being too big, which made it so it couldn't close the way it should have. That issue has been fixed, however, and it was sent to be reprinted. The new part still doesn't fit together correctly, which is why this part may have to have some major changes made to it. Even without putting the padding in the box, or the box fitting together, it still helps to sever the connection of a phone sidetracking people. It is tough to say though whether the part will turn out to work or not.

Fig. 12: First 3D print of the "Think Tank" made on the Cube Pro

Fig. 13: Second 3D print of the "Think Tank" made on the MakerBot

C. Arduino

Along with the 3D projects and work with the Pi, the RET program worked with Arduinos. The Arduino system is similar to that of the Raspberry PI, except that it is a much simpler system (see Louis, L. for more). However, it isn't nearly as user-friendly as a Pi. So when tasked with writing code on it, a few of the RET participants struggled at first. Thankfully, there were a few tutorials online to help learn how the Arduino worked. These tutorials turned out to be very neat and very helpful for someone who is new to Arduinos. After completing the tutorials, the task was then given to create a Christmas themed design incorporating the use of the Arduino into it. This is where the project got difficult. The task was to write a computer code for something that had just been introduced. However, the project proceeded, and with some luck, a design and a code were produced. The more added to the code though, the harder it got to write the code as issues began to emerge with the code. Thankfully, help was able to be found in some people who knew how to use Arduinos and were very helpful. They showed where the code went wrong and how to fix it. At the end of the first day of working with the Arduino, the program ran smoothly and operated on a breadboard. After the circuit was working, the next step was to implement it into Legos to make a Christmas design. This task

seemed rather simple but turned out to be far from it as trying to fit the lights in between the Legos turned out to be rather challenging. So this process took a while to get it all together. Eventually, the Legos did manage to snap into place and made a nice little Christmas tree. The only issue with the Christmas tree is that all of the wires were hanging off of the back, but given how it was made, these wires seem to be acceptable.
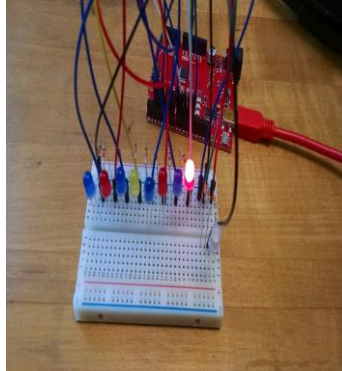

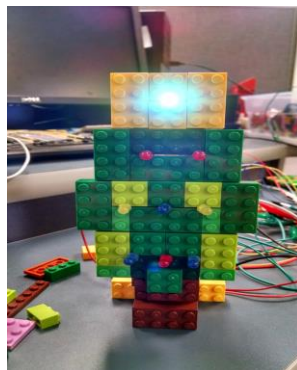Fig. 14: LED circuit made using the RedBoard and the Arduino uno coding software

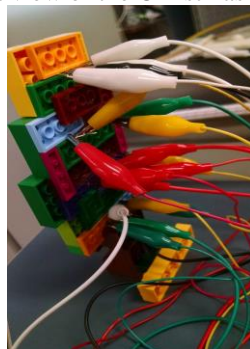Fig. 15: Front view of the Christmas design created

Fig. 16: Rear view of the Christmas design

3. Lessons learned

While the RET program worked on multiple engineering projects, it managed to teach so much more than just the basics of one area. It broadened the spectrum of what is out there to explore through engineering. The program taught its participants about various forms of engineering, as well as the basics of what that field has to offer. The experience of participants in the program varied among them, but each person got to learn something new. The different fields explored during the program ranged from computer engineering to robotics engineering, while covering most of what laid in between. This is part of what makes the program such a great experience for the participants.

Along with teaching about the different fields of engineering, the program also helps participants learn new skills. Participants are given task to do that sometimes requires they use equipment or do things that they have never done before. This action of taking them out of what they normally do allows the participants to learn new skills. This is a wonderful aspect of what the program does. These new skills that are picked up during the summer are skills that can be used in everyday life to help better people. The skills include things like computer coding, soldering wires, and mechanical skills. Another skill that every participant learns is how to see the issues in a piece of equipment in order to see its limitations and use it to its full potential. This skill makes for a great ability, as it allows participants to see this process in their everyday life. With this skill one could easily find the right object to do the task they are trying to accomplish.

Acknowledgements

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