Summer Engineering Academy for First-year Students in STEM: Making the Transition to College Through Coding and Robotics

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This Complete Evidence-Based Practice paper presents the Summer Engineering Academy at the University of the Incarnate Word (UIW). The camp was designed for first-year freshman and transfer students with a declared Science, Technology, Engineering and Mathematics (STEM) major. The main goal of the program was to support and encourage the incoming freshmen's transition into pursuing science, math and engineering degrees at the UIW. In order to achieve this goal, the objectives of the camp were (1) To address students' academic readiness and self-efficacy for a rigorous STEM degree; (2) To strengthen incoming freshman students' skills in communication, effective collaboration, and data analytics through coding and hands-on robotics activities. The Summer Engineering Academy was a free one-week camp that provided service to a low-to-moderate income student population in STEM major. The camp participants were from diverse STEM fields that included engineering, biochemistry, nuclear medicine science, biology, computer information systems, meteorology, 3-D animation & game design. We observed that upon completion of the camp, the participants were motivated and excited about starting their first year at the University of the Incarnate Word, had an understanding of the career options in their STEM fields, and achieved a basic understanding in computer programming and engineering design. In this paper, we describe the details about the Summer Engineering Academy based on the teaching materials, the results of students' evaluations, lessons learned and the future work.

Introduction

Soon-to-be high school graduates from around the world apply to the University of the Incarnate Word for their STEM program. Many of them have yet to fully comprehend the expectations and demands that come along with becoming a first-year student[1,2,4]. Laanan stated that understanding students in transition is not an easy task, it requires that we have understanding of what students bring to the college experience; that is, prior academic preparation or training, life experiences, and cultural experiences[8]. Personnel and institutional resources must be in place to assist the incoming freshmen in STEM fields to adjust to situations that can be overwhelming. During this transition academic self-efficacy will be the driving force that becomes the cornerstone of freshmen success[6-9].

Many colleges and universities in the United States offer summer programs for their incoming students with the primary goal to promote college retention and improve completion rates by providing students with the academic and social skills needed to succeed in college prior to beginning their undergraduate studies[11,12]. These programs have been found to positively affect participants' perceived social fit, college preparation, networking relationships between students, and coping skills, and to decrease student anxiety in addition to providing a familiarity with the campus and a review of STEM content.[13,14] Summer bridge programs offer academic reviews in mathematics, physics, chemistry, English, computer program tutorials to better prepare students for their freshman STEM courses in addition to offering general information about their university/college, financial aid, and advising to help students get acquainted with the campus[11-15].

This paper presents the Summer Engineering Academy, the camp designed for first-year freshman and transfer students with a declared STEM major, at the University of the Incarnate Word. The University of the Incarnate Word is located in San Antonio, Texas, which is the second-largest city in the state. The UIW has a total global enrollment of over 11,400 students, making it the fourth largest private university in Texas. The University of the Incarnate Word offers bachelors and master's degrees in more than 80 disciplines, and doctoral degrees in seven fields of study. The institution welcomes to its community persons of diverse backgrounds, which was the main perspective of the Summer Engineering Academy. We wanted to establish a summer program that could support many different STEM majors in the transition to the University of the Incarnate Word culture.

Objectives

The Summer Engineering Academy was a free one-week camp that provided service to a low-to-moderate income student population in STEM major. The camp participants were from diverse STEM fields that included engineering, biochemistry, nuclear medicine science, biology, computer information systems, meteorology, 3-D animation & game design. The objectives of the camp were twofold:

1. Address students' academic readiness and self-efficacy for a rigorous STEM degree.
2. Strengthen incoming freshman students' skills in communication, effective collaboration, and data analytics through coding and hands-on robotics activities.

The outcome of the first objective was accomplished by the presentations made by the guest speakers from various industries, such as Southwest Research Institute, Boeing, Rackspace, and First Year Engagement Office at UIW. Their presentations emphasized the following skills/attributes that students need in order to be successful in college and career:

- Time management – class attendance, planning, class assignments.
- Networking and communication – soft skills, participation in student clubs, gaining information about internships.
- Creativity and problem solving – applications of MATLAB[5] used in industry by STEM experts.

The outcome of the second objective was achieved by developing and implementing technical solutions to problems in computer programming, robotics, and presenting the results orally and in a written final report. Specific outcomes in analytical skills were:

- Conceptual mastery of basic programming constructs in MATLAB[5]: variables, functions, loops and conditional statements
- Understanding of basic robotics: sensors, actuators, and artificial intelligence
- Moderate understanding of abstraction, computational thinking and development

Table 1: The objectives of the Camp were aligned with the ABET learning outcomes[3].

Activities	Learning Objectives
● Introduction to MATLAB and its applications	● An ability to apply knowledge of mathematics, science, and engineering
● Activities such as Blood Pressure analysis and Aurdino music projects	● An ability to design and conduct experiments, as well as to analyze and interpret data
● Designing and building a roller coaster using PASCO bridge set and designing a gate at the end of the track to avoid the falling of the car. ● Recognizing that there is more than one solution to a problem.	● an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability ● An ability to identify, formulate, and solve engineering problems
● Students from various STEM fields participated in the Camp and were given various opportunities to work in teams. They were also required to communicate effectively with team members, both orally and in writing	● An ability to function on multidisciplinary teams ● An ability to communicate effectively
● Guest speakers talked about the importance of being professional and ethical in their careers	● An understanding of professional and ethical responsibility
● Presentation by the Director of First Year Engagement and Professional Development emphasized on the importance of various skills that are necessary for life-long learning	● A recognition of the need for, and an ability to engage in life-long learning

In the following sections, we described the details of the program, results of the camps, lessons learned and future work.

Recruitment

The camp coordinators used various types of communication channels in the recruitment process for the camp. In 2016, the camp was mainly advertised through summer orientation sessions and advising through School of Mathematics, Sciences and Engineering faculty. We created and distributed tri-fold brochures that were included into the freshman orientation package by the First-Year Engagement (FYE) office. The FYE office also contacted the students and their parents via phone calls and emails. Even though, this approach was effective, we did not reach our target of number of participants. Therefore, we changed our strategy to advertise the camp and started planning earlier in the following year. In the Fall of 2016, we worked with the UIW's web development office to create a web site for the camp. During the month of March 2017, First Year Engagement team incorporated Summer Coding Academy information into their prescheduling questionnaire directing the interested students to the camp's web page

(http://www.uiw.edu/summercoding2017). The web site contained information about the camp and provided the interested students with a simple application process. We also attended the UIW's first year student orientations to promote the camp and meet with the parents to emphasize the importance of the camp. We designed a separate package that consisted of the camp information for the parents. First Year Engagement and Career Services & Professional Development team reached out to the students and their parents via texts, phone calls and emails to follow up with them about the camp.

Program

The camp participants were provided with a detailed schedule that had the computer and robotics laboratory locations and times. The students were punctual throughout the week and engaged in active participation. The camp was composed of morning and afternoon sessions, shown in Table 2. The morning sessions started at 8:30 am and consisted of creative programming and presentations by guest speakers from industry.

Table 2: Summer Engineering Academy - Daily Schedule

Time/Day	Monday	Tuesday	Wednesday	Thursday	Friday
8:30am	Arrive & Breakfast				
9:00am	*Introduction & Welcome*	MATLAB	MATLAB	Topic of Day:	Final Project
9:30am	MATLAB	Topic of Day:	Topic of Day:	ARDUINO MUSIC	Setup
10:00am	Topic of Day:	Functions & Selection	Data Analytics	Project	
10:30am	Fundamentals	*Conditional Statements/ Loops*	*File Input/Output*		Final Project
11:00am	*Guest Speaker*	*Guest Speaker*		*Guest Speaker*	Presentations
11:30am	*RACKSPACE*	*SwRi*		*BOEING*	
12:00pm	Lunch - Bonilla Science Hall				
12:30pm					
1:00pm	ARDUINO ROBOT CAR	PASCO	ARDUINO MUSIC	*Final*	
1:30pm	Project	ROLLER COASTER	Project	*Presentation*	
2:00pm		Project		*ReportWriting*	
2:30pm				Project	*End of the camp*
3:00pm					
3:30pm				*Guest Speaker*	
4:00pm				*UIW*	
4:30pm	Departure				

The morning curriculum was developed for students who did not have any scientific programming experience in MATLAB or any language. The purpose was to inspire the students, build confidence in their coding skills and engage them in creative problem solving activities. In the morning sessions, we also promoted STEM career opportunities by inviting guest speakers from industry. The representatives from Rackspace, Southwest Research Institute (SwRI) and Boeing discussed the importance of soft skills, networking and internships during the academic years and career opportunities in various STEM fields after graduation. The afternoon sessions started at 1:00 pm and consisted of hands-on robotic challenges. The projects included developing an Arduino smart car, designing a PASCO roller coaster and implementing an Arduino music box. The objectives were to build confidence in the student's programming skills, engage them in engineering design process, increase their creativity to solve problems and

communicate effectively while working as a team. The participation of the University of the Incarnate Word undergraduate mentors aided in the effectiveness of the academy. Throughout the afternoon sessions, the student mentors provided guidance in programming and designing the electronics to build the robots. In addition, the camp mentors arranged tours around the campus based on the students' Fall class schedule. The main goal was to ease the nervousness of the first day of school, by providing a campus overview for the location of the classrooms.

Morning Session Activities

During the first day of the camp, participants were given an overview of the morning session activities. They were introduced to the basic programming skills in MATLAB through programs and games provided by MathWorks[5]. Table 3 shows the summary of the topics that were covered in the morning sessions during each day of the camp.

Table 3: Summer Engineering Academy – Major topics covered in the morning sessions

Day 1	Day 2	Day 3	Day 4	Day 5
Introduction to MATLAB[5]: How to use MATLAB as a sophisticated calculator, create plots. **Matrices and Operators:** How to define matrices, extract parts of them and combine them to form new matrices; to use operators to add, subtract, multiply, and divide matrices; to learn the rules for the order of operations.	**Functions:** How to define a function to allow input to it when it initiates its execution and output from it when it is done. **Programmer's Toolbox:** How to use built-in functions; to get input from the keyboard; to print to the Command Window, and to plot graphs in a Figure window.**Selection & Loops:** How to use relational operators, logical operators; for-loop and the while-loop	**Data Analytics:** Study the data types in MATLAB; how to produce heterogeneous collections of data via structs and cells. **File Input/Output:** How to create, read from, and write into MAT-files, Excel files, text files, and binary files.	**Final Project: Research & Development: Final Project: Presentation & Report Writing:** Teams will prepare a Power Point presentation and a report for their findings.	**Final Project & Reflections on the Camp:** Individual presentations and reports.

During day 3, students were assigned a project to analyze blood pressure in order to practice data acquisition and analytics. They were introduced to the basics of the topic, such as what blood

pressure was, stages of blood pressure, effects of exercise on blood pressure, etc. The project was outlined as the following:

a. Measure resting blood pressure
b. Raise blood pressure (stressed)
c. Measure stressed blood pressure
d. Import data
e. Analyze data in MATLAB

Figure 1 shows the collected and analyzed day.

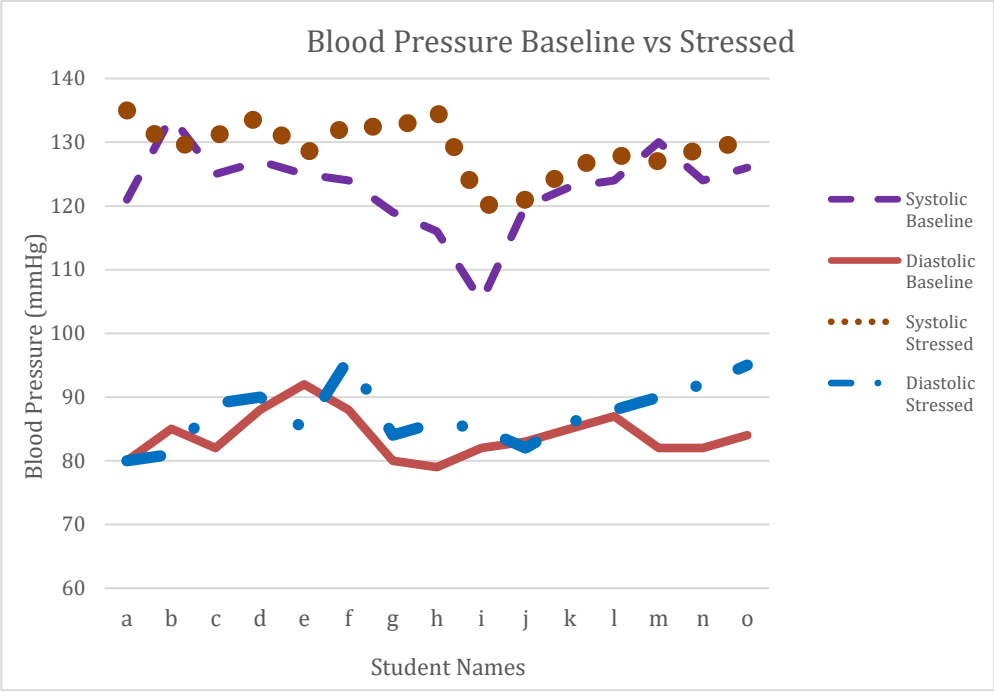

Figure 1. Blood pressure project – Data Acquisition and analytics

Once the students collected the data before and after blood pressure measurements, they imported the data and showed the differences by analyzing the data in MATLAB. This was a good example for data acquisition and analytics, because the students could relate to the real-world problems and provide a solution to understand the differences.

Afternoon Session Activities

Each afternoon session was filled with hands-on activities and competitions. During Day 1, the project was to build a robot car[10] that was controlled by a cell-phone application. Students built the car using an Arduino Uno board as a controller and designed a cell-phone application to navigate through an obstacle course. Figure 2 (b) shows the building of the car.

During Day 2, students built a roller coaster using PASCO bridge set. Students grouped themselves into two teams to build and test the roller coaster. Once the roller coaster was complete, they were challenged to build a gate to stop the car from falling off the track. Figure 2 (c and d) shows students testing the stability and function of the roller coaster track using the cart.

Figure 2 (a-f). Student activities in the afternoon sessions (the images are assigned to the letters in clockwise direction).

During Day 3, students learned about signals and frequencies. They worked with an Arduino board to design a music box. The box consisted of ten LED lights, one speaker and an Arduino Mega board. They built box and developed the music by programming the board. They could be able to code different tunes, such as Christmas music, favorite movie themes, etc. Figure 2 (e) shows the final music box. This was another fun project for the participants to demonstrate how they could build and customize an equipment to their preferred application.

Results

An application process was established through the camp's website. The interested students were asked to upload a professional personal statement (250 words) that described their interest in attending the camp based on their academic and career goals. These documents were uploaded through the camp website and reviewed by the camp coordinators. The Summer Engineering Academy was evaluated through the students' pre and post survey responses and their final project presentations that included PowerPoints and written reports. These final reports were in the same format as the statements in the application package. This allowed us to evaluate the performance of the students before and after the camp.

Individual Oral Presentations:

Students were required to present their coding camp experience with faculty, their peers, and family members on the last day of the camp. Their individual presentations were evaluated using the following evaluation rubric.

Table 4: PowerPoint Presentation Evaluation Rubric with scoring of 1: Poor, many requirements not met, 2: Fair, some requirements met, 3: Good, meets most or all expectations, and 4: Outstanding, exceeds expectations.

Content Requirements with a maximum score of 24 points
Title slide - student must come up with their own presentation title. Slide must also have the presenter's name.
Introduction slide in which the student should list their major, and educational background. They can also mention why they choose UIW.
Motivation slide – This slide must contain any previous experience in coding and the motivation or inspiration for participating in this camp.
Coding camp projects – four to six slides showing the projects that they worked on with pictures.
Reflection slides – One or two slides containing challenges faced and lessons learned.
Summary slide – concluding slide with acknowledgements.
Design Requirements with a maximum score of 20 points
Font, background and colors of the slides are appropriate and consistent.
Slides are free of spelling and grammatical errors.
The information presented is in logical sequence/structure.
Slides do not contain too much text such as paragraphs or lengthy sentences.
Pictures are clear and helps in understanding the projects. Not too many pictures on one slides.
Presentation Requirements with a maximum score of 16 points
Presenter spoke slowly and clearly.
Presenter did not read from the slides which gives an indication that the presentation was rehearsed.
Presenter showed enthusiasm in explaining the content/projects and made eye contact with audience.
Presenter answered audience questions in a polite manner.

The presentations indicated that more than 77 % of the camp participants exceeded the expectations of overall score on their final PowerPoint presentation. The oral presentations included students reflections on projects and possible integration of MATLAB programming into their respective STEM fields.

Figure 3: Student presenting her projects and reflection of the camp

In addition to the PowerPoint presentations, students submitted a written report for the end of camp. Table 5 shows samples of the final reports submitted by the students that included professional reflective statements.

Table 5: Samples of student final reports - reflective statements

"My expectations were a little bland. I was afraid that the camp was going to be a lot of papers and lessons. I thought it'd be more like a workshop, but to my surprise, there was individual help with a small group of people learning all these skills together. I was very happy with the patience and helpfulness of the mentors. They helped us each individually, gave us step by step instructions, and gave us a lot of time to figure things out and work through the problems. The mornings were great for learning new skills. Even though it's pretty tough gathering all that information in just a week, I have just begun with MATLAB and I am certain I will continue to use it in the future."
"…the camp turned out to be a lot more enjoyable than I would have imagined. It served as an opportunity to become more familiar with the University of the Incarnate Word campus before my first semester classes began, and meet more people. I had very little prior experience in coding before this camp. I had taken a course in computer science principles in high school, but their curriculum was based off of code.org, which doesn't really teach a lot about actually using the keyboard to type code (their program utilizes a drag and drop style, with functions, strings, and variables already defined). MatLab was like my introduction to coding (which I hope to continue to learn and improve at on my own). As I become more proficient in MatLab, I hope to be able to utilize it to collect and visualize data that I collect in research, or maybe even write some sort of app in it.

Pre and Post Survey Results

Table 6 shows the daily post camp survey results. The purpose of this survey provided the camp coordinators with an instant feedback from student to evaluate the daily program. This process was beneficial and productive for the coordinator to identify the camp participant's interests and challenges.

Table 6: A sample of Students' responses to the open ended questions on Summer Engineering Academy morning and afternoon sessions

1. What was your favorite activity in the Summer Engineering Academy morning session? What changes would you make to this activity? ● The MATLAB practice, I would just make it longer ● Building the car, I would make it harder though ● The guest speaker presentation ● Practice Coding, learning the code ● The MATLAB coding training ● Putting together the car ● Solving the equations and then putting them into MATLAB ● The use of the functions to find the solutions of formulas ● Learning how to use the functions in MATLAB ● Transfer excel files to MATLAB ● Big data analysis ● The blood pressure testing and learning to use MATLAB to visualize it ● Making the Arduino soundboards to make the Star Wars theme song ● Creating music using MATLAB
2. What was your least favorite activity in the Summer Engineering Academy morning session? What changes would you make to this activity? ● Creating Loops ● Learning of the functions ● Trying to figure out how to get the square graph
3. What was your favorite activity in the Summer Engineering Academy afternoon session? What changes would you make to this activity? ● Guest speakers ● Reflecting on what we have learned in the camp ● learning how to make loops and star wars themed song ● Building the roller coaster and how we were working together to make things ● The robot race
4. What was your least favorite activity in the Summer Engineering Academy afternoon session? What changes would you make to this activity? ● Making a presentation and a word document ● Learning about the graphing ● Editing and making graphs ● It was easy to think, but hard to code ● The building of the robot

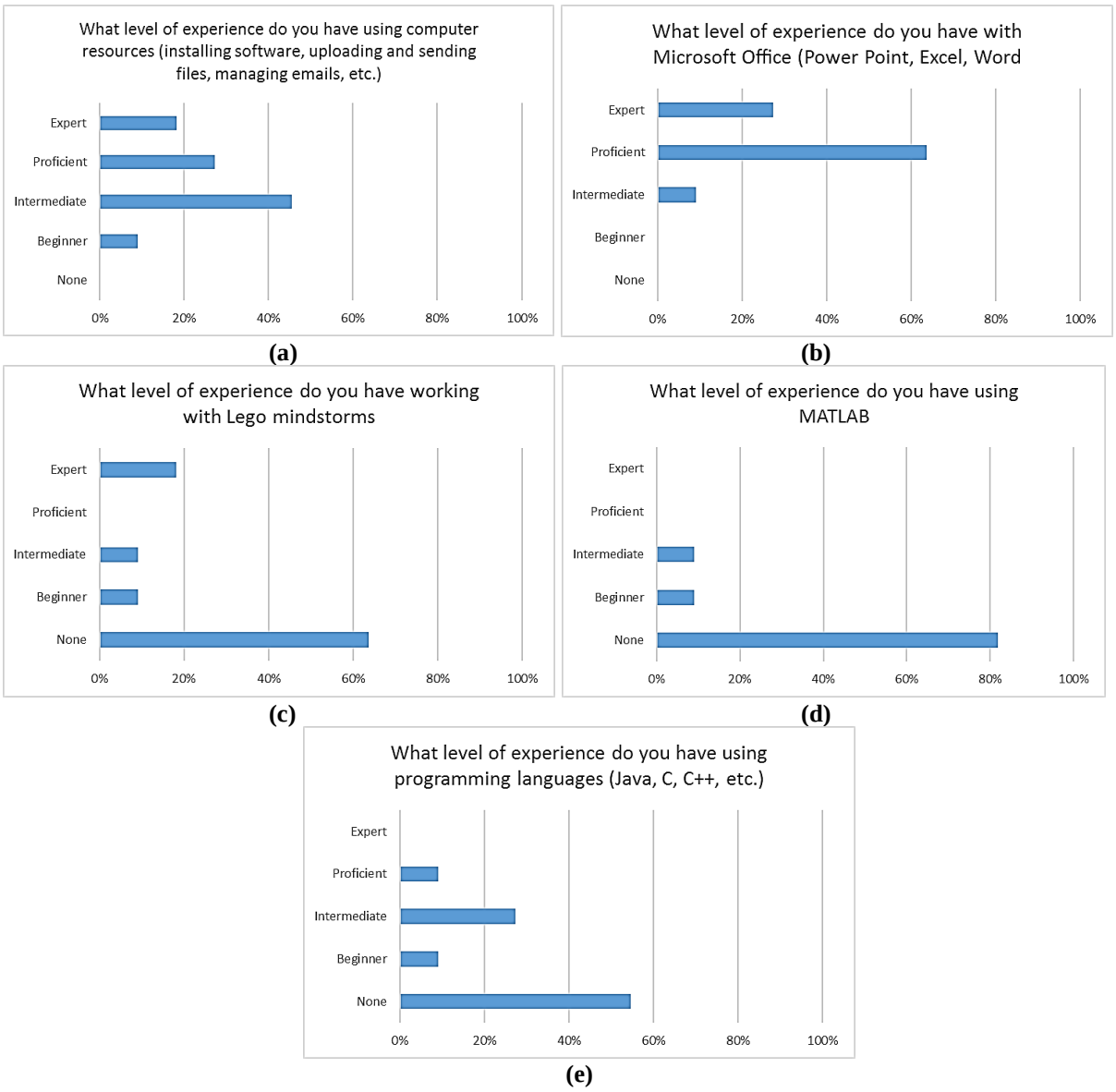

Figure 4 (a-e): Pre-Survey Results indicating Level of Experience prior to Summer Engineering Academy (N = 11)

Figure 4 (c, d) show that about 82% of students came with zero experience in using MATLAB, and 64% with zero experience in using Lego Mindstorms. The goal of Summer Engineering Academy was not only to teach students the basics of computer programming but to improve their problem solving and critical thinking skills by incorporating projects such as measuring blood pressure and analyzing it with MATLAB, building a roller coaster using PASCO building set and designing a gate so the car does not fall off the coaster, etc. The table below shows student's response to post-survey questions. Results indicated that about 67% of students agreed that their skills have improved and all the participants either agreed or were neutral about their understanding of MATLAB.

Table 6: Post-Survey Responses

Survey Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
The Summer Engineering Academy has improved my problem solving skills.	67%	33%	0%	0%	0%
The Summer Engineering Academy has improved my critical thinking skills.	67%	33%	0%	0%	0%
The Summer Engineering Academy has improved my collaboration skills.	67%	33%	0%	0%	0%
I would be interested in participating during next year's Summer Engineering Academy as a Camp Mentor.	0%	89%	0%	11%	0%
I have a better understanding, and knowledge, of how to write *functions, scripts, loops and if/else statements* in MATLAB.	56%	22%	22%	0%	0%

Conclusions - Lessons Learned and Future Work

There were total of 15 students that showed interest and applied to the program. However, we had 11 participants in the camp. The camp dates coincided with the hurricane Harvey. This prevented some students from traveling to San Antonio. However, the Summer Coding Academy 2017 had an increased number of camp participants compared to last year's attendees (nine students). The survey results, students' written reports, and their project presentations, also, reiterated the students' strong interest in the camp. The participants were motivated and excited about starting their first year at the University of the Incarnate Word, had an understanding of various career options in their STEM fields, and achieved a basic understanding in computer programming and engineering design.

The goal for the Summer Coding Academy 2018 is to promote the camp earlier in the year. We plan to work with the Admissions office to attend their programs to promote the camp to the high school students who are interested in applying to the University of the Incarnate Word. We plan to have a booth setup to promote the coding camp during the Admission's Fall and Spring semester high school recruitment programs. The option of combining the camp with field trips to the local industries in STEM fields is also considered for future.

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