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Redesigning a Summer Math and Engineering Bootcamp for Virtual Instruction During the COVID-19 Pandemic

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Redesigning a Summer Math and Engineering Bootcamp for Virtual Instruction During the COVID-19 Pandemic

This Complete Evidence-Based Practice paper discusses the redesign and transition of a Math and Engineering bootcamp to an exclusively online format for compliance with safety protocols required during the COVID-19 pandemic. The main goal of the bootcamp was to increase the graduation rates in engineering (ENGR) and computer science (CS). The four- and six-year rates (~17.7% and ~64.5%), are below the University's average graduation rates (~ 33.1% and 67.4%, respectively). We designed the bootcamp to improve graduation rates by a) improving students' knowledge and confidence in required math topics, b) familiarizing students with CS and ENGR majors through problem-based learning activities that integrate skills from multiple disciplines.

Calculus and other math courses serve as prerequisites to most of the ENGR and CS courses. Therefore, each time a student fails a math course, his/her graduation is delayed by at least one semester. In addition, some upper-division courses are offered only once a year, so delays in completing their prerequisites may even delay graduation a year or more. Some students are not privy to prior exposure to CS and ENGR and only learn about the discipline after taking multiple classes in the major. As a result, some students change majors after they have spent multiple years in their original major, which also delays graduation.

The bootcamp recruited incoming freshman and transfer students with declared majors in CS and several ENGR majors. The bootcamp accepted students from all populations but prioritized underrepresented minorities and first generation students. We observed an increase in diversity compared to previous bootcamp, due to increasing participation of female students.

The three-week bootcamp transitioned to entirely-virtual, comprised of practicing Pre-Calculus math problems with educational software (ALEKS) and developing solutions to engineering projects with synchronous video conferencing instruction via Zoom. Students received instruction and assistance (via Zoom) from faculty and student assistants throughout the bootcamp. Finally, students integrated four projects that focused on different disciplines, including programming a robot to detect and circumnavigate obstacles, designing and constructing a truss bridge, modeling the dynamics of a trebuchet, and programming the robot to implement a PID Controller. Four out of the seventeen students successfully completed the final challenge, which required designing and building a truss bridge capable of handling a certain load, programming the robot to find its way to find entrance and cross the bridge, and reaching the trebuchet to load the payload.

By comparing responses in pre- and post-bootcamp surveys, students indicated an increased confidence and ability to solve problems in Algebra, Geometry, Trigonometry, Pre-calculus and Calculus. Additionally, the students expressed an increase in realizing the importance of math in learning CS and ENGR concepts. The paper will discuss the quantitative and qualitative results of the surveys. The authors will assess the students' performance in the ALEKS, discipline-based projects, as well as the student success in the math courses during the Fall 2020 online semester.

Faculty reflections on the online bootcamp and the differences with the previous year will highlight opportunities for improving virtual bootcamp delivery for preparing future engineers.

I. Motivation

The Math and Engineering bootcamp was established at California State University, Chico (CSU Chico) in Summer 2019 [1]. During the COVID-19 pandemic, faculty decided to continue holding the bootcamp in Summer 2020, but in an exclusively online format for compliance with required safety protocols. The paper explains how the bootcamp contributed to the campus graduation goals, the improvements that were made to the Summer 2019 bootcamp to develop an online and more inclusive bootcamp, the challenges of delivering an online bootcamp, how we attempted to address the challenges, and how we can improve our experience in the future. The targets of Graduation Initiative 2025 at CSU Chico are a four-year graduation rate of 41% and a six-year graduation rate of 74%. The goals were set in accordance with the need for the educated workforce in the State of California [2]. The graduation rates in ENGR and CS majors need to increase to achieve the target four-year and six-year graduation rates.

The curriculum of ENGR and CS involves a series of Math courses which are pre-requisites of the higher division courses in each major. Students start taking the series of the Math courses in their first semester; if a student is placed in one of the pre-requisites of Calculus such as Precalculus Mathematics (MATH 119), Trigonometry (MATH 118), or Concepts and Structures of Mathematics (MATH 110) instead of the Calculus, at least one semester delay in the graduation can occur. Additionally, if a student fails one or more of these pre-requisite chains, the student's graduation will be delayed by at least one more semester. Another factor that aggravates this situation is that most of the higher division courses are only offered once a year at CSU Chico and are not offered during the summer or at other universities across the nation. Therefore, the importance of passing the math courses at the scheduled semester is evident of the study plan to reduce the time-to-graduation.

About 19.1% of the incoming freshman and transfer students in the College of Engineering and Computer Science did not enroll in Calculus as their first math course in Fall 2020, but rather one of the mentioned pre-requisites of Calculus. This means that 19.1% of our ENGR and CS freshman students take more than four years to graduate after they enter the university. This situation is more convoluted when a student fails one of these pre-requisite courses; the most recently available data shows that 15% of the students failed MATH 118, 24% failed MATH 119, and 37% failed MATH 120. There are also students who withdraw from these courses [3]. These students need to retake the math courses consequently, which adds to the duration of their studies towards their degree. Therefore, student success in passing the math courses is a key factor in reducing the time-to-graduation in the ENGR and CS programs.

One other observation that leads to a longer time-to-graduation in ENGR and CS majors is students changing their majors after a year or two years from the beginning of the program. Available data [3] shows that 60% of the first time students who changed their majors made this change during the freshman year and 28% of them change their major during the sophomore year. This can be a result of students not having enough information about the major. Hence, familiarizing students with the majors and showing the importance of math to them would play an important role in student success towards graduation in the major they choose.

The online Engineering Math and Project bootcamp was designed to address the three discussed barriers in students' graduation: 1) students' weakness in pre-requisites of Calculus, 2) students' weakness in mathematical concepts that are fundamentals of higher division engineering courses [4], [5], and 3) students not having sufficient information about their majors. The summer bootcamp was held to increase student knowledge and skills in the pre-requisites of calculus. The bootcamp was held close to the start of the Fall semester to keep freshman and incoming transfer students fresh on the math topics that they practiced during the bootcamp. The solution to the third barrier was embedded into the bootcamp by holding project sessions in different majors [6].

The expected outcomes from the bootcamp project included:

1) Students would be more prepared to pass the prerequisites of Calculus and consequently would decrease the time-to-graduation.
2) Students would make more informed decisions when selecting their majors and would less likely need to change their majors. This would also decrease the time-to-graduation.
3) Students would have a better understanding of the necessity of knowing the mathematical concepts in order to succeed in their major courses.

II. Project Description

The bootcamp was designed to address the issues discussed in the previous section by 1) working on the student knowledge and skills in Pre-calculus Math and 2) implementing Project Based Learning (PBL) sessions to help students understand the importance of the math in their disciplines as well as be involved in hands-on projects. The hands-on projects were selected from Electrical and Computer Engineering, Mechanical, Mechatronic Engineering and Sustainable Manufacturing, Civil Engineering, and Computer Science majors, to provide a taste of each major to the incoming freshman and transfer students. The addition of Civil Engineering major to the 2020 virtual bootcamp compared to the in-person 2019 bootcamp could help us attract and engage Civil Engineering students in the bootcamp, help them improve their math knowledge and skills, and be engaged in an important Civil Engineering project as well as other projects. This section of the paper explains how the online bootcamp was formed and implemented.

A) Financial Support

The online bootcamp was considerably supported by the CSU Chico Office of Undergraduate Education. Also, a small amount of the needed funds were provided by donors who contributed to this project on the 2020 Giving Day. Funds were used to cover costs, including ALEKS software package for each student, project hardware and materials that were shipped to the students' residence, shipping fees, awards for the winners of engineering competitions, and stipends for faculty and student mentors. Since the bootcamp was held online, the university housing and residence assistance costs were eliminated, and hence the total cost was reduced significantly.

B) Student Population

The target participants for the online summer bootcamp were incoming freshman and transfer students with a focus on underrepresented students, minorities and students with lower high-school GPAs. Seventeen incoming transfer and freshman students from multiple departments of College of Engineering, Computer Science and Construction Management were enrolled in the Online Summer 2020 Math and Engineering Bootcamp. Additionally, one incoming student from the Math Department participated in the bootcamp who was interested in learning more about the engineering majors as she intended to pursue her minor in Civil Engineering. As shown in Table 1, most of the students were from underrepresented and minority groups. To recruit students, flyers were sent out to Chico Unified School District to inform the high school students who were graduating in 2020. The announcement flyers and applications were additionally posted on the departments of College of ECC websites. Also, the incoming students were informed about the bootcamp opportunity through a virtual info session that the college held in May 2020. The list of the students who were admitted and intended to enroll in engineering and computer science majors were provided by the Office of Registrar. Students who had lower GPAs were contacted first by email to make appointments for phone calls. Then, the students who had not responded to the emails, were given calls to be informed about the opportunity and be encouraged to participate. After we received the applications from the students with lower GPAs, students from all target majors were contacted for a more inclusive recruiting. One of our challenges in recruiting students has been convincing the students that they need to improve their math skills. It has been difficult to convince them that this opportunity would help them to reduce their time-to-graduation, and encourage them to dedicate some of their summer time to math and engineering projects. To address this issue, the College of ECC is planning to promote the next bootcamps in earlier conversations with the admitted students to bring students' attention to this opportunity.

Four of the students who participated in the bootcamp were female students. This was a 16% increase in female students' participation compared to the last year leading to an increase in diversity. Table 1 summarizes the percentages of student population in the bootcamp.

Table 1. Percentages of student population from different ethnicities

Ethnicity	**Percentage of the population**
White	22.2%
Hispanic	44.4%
African American	11.1%
Asian	11.1%
Did not identify	11.1%

C) Bootcamp Implementation

The three-week online summer bootcamp was structured as follows:

Morning of Day 1: Orientation and Math Evaluation
Mornings of Subsequent Days: Math tutorials and Problem Solving
Monday-Thursday Afternoons: Project-Based Learning

Third Friday: Final Challenge Demonstrations and Competition

During the morning sessions, students built their math skills through a self-guided learning tool called ALEKS [1]. The Zoom Link of the sessions was sent to the students before the bootcamp. There was an orientation on the first day to familiarize students with the overarching goals and rules of the bootcamp, introduce the student mentor, lab assistant and faculty who were engaged in implementing the bootcamp, distribute the ALEKS Software codes and run the pre-bootcamp survey. The built-in ALEKS initial knowledge test tool was then utilized to assess the students' mathematical abilities. The ALEKS software was then automatically customized to the math level that was pertinent to the assessed skills of each student. The package selected from the ALEKS packages was STEM pre-calculus which included algebra to pre-calculus. A student mentor and a faculty mentor supervised students during the math sessions each morning during the three weeks in Zoom virtual sessions. The students' progress was monitored through the math tutoring and the ALEKS software and assessed during the mentorship sessions. The math tutor was available during the entire math session to answer students' questions and reported the students' attendance to faculty mentor. The faculty mentor monitored the progress of the students in ALEKS, was in contact with the math tutor to work with the students who had slower progress, and worked directly with such students to help them improve their math skills. The advantage of the bootcamp math sessions over taking the pre-calculus course during the summer is that students do not pay the extra summer tuition and housing, the student is not stressed by learning the concepts for a passing grade, as well as the pre-calculus and its pre-requisites are not normally offered during the summer.

The afternoon sessions of the bootcamp were four hours a day, and were designed to introduce students to the relationships and distinction between Mechanical Engineering, Electrical Engineering, Computer Engineering, Civil Engineering and Computer Science majors. The activities were selected to present projects in multiple majors, and help them realize that many of the ENGR and CS careers rely on the application of math and critical thinking. During the 2019 bootcamp, students worked in teams of two students. During the 2020 online bootcamp students worked on the projects individually. All the required materials for the projects were shipped to the students prior to the bootcamp. Additionally, since students were not allowed to be on campus during the summer due to the COVID-19 pandemic, faculty played videos of campus facilities to familiarize the students with the available resources that they could use once they would be on campus.

1. Computer Science Project

Computer Science faculty supervised the first three days of the bootcamp, which familiarized the students with programming robots. Students practiced programming robots (DFRobot Maqueen), featuring *micro:bit* ARM-based microcontrollers, using the MakeCode graphical block-based programming environment. Students first learned basic operations of the robots by controlling their motors, playing audio, and displaying messages on an LED. Students used these operations to write procedural algorithms for a creative "celebration" with a combination of audio, display, and movement.

Next, students learned how to read from the robot's sensors and gained exposure to boolean logic by applying conditions to decisions (if, else) and loops (for, while). They applied these concepts to a challenge of moving forward until the robot reached a target area--indicated by a surface of a contrasting color--and then initiating their robot's celebration.

The final challenge of the Computer Science project was to create an algorithm that directed the robot to drive around an obstacle without collision and then continuing forward until it reached its target area. Upon reaching the target area, it would perform a celebration to indicate it had completed the challenge. Students seeking additional challenges were encouraged to use variables and functions to generalize their algorithms to accommodate different surface colors and obstacles of different sizes.

Since students worked on the challenges at home instead of a shared university lab, the challenges had to account for different environments. The robots only move well on hard surfaces so students sought out the most appropriate area in their house, which included desks, floors, or flattened cardboard boxes. The robot's infrared sensors indicate surface reflection in binary to indicate either a light (1) or dark (0) surface below the robot. Students worked with a variety of different surfaces so they also sought a thin material in a contrasting color from their surface. For example, on dark surfaces, white printer or notebook paper provided effective contrast.

Likewise, students had to find their own obstacles to place between their robots and the target (contrasting surface) area. We directed students to find a household object that was at least the size of the robot. Students often chose either a book or the cardboard box in which their bootcamp supplies were delivered.

Overall, students were engaged in the challenges and demonstrated their unique approaches by showing the robots on their webcams or broadcasting their computer screen (via Zoom's Share Screen feature) to show their programs. Students downloaded and backed up their programs so that they could reference and reuse parts of the code in the later modules.

2. Mechanical Engineering Project

During the second three days of the bootcamp afternoons, students worked on a project in the field of mechanical engineering, developed a mathematical model of a physics problem, used Excel to calculate the model, and compared the theoretical results to the real problem. The trebuchet, a medieval catapult driven by a falling, hinged counterweight, was chosen for the physical model for it could be simulated with progressively increasing detail: as a simple catapult, with a "see-saw" hinged counterweight, and, finally with a sling.

First, the students were given the task of calculating the trajectory of a projectile given initial velocity, V_o, and launch angle, θ, Most students lacked experience with a spreadsheet and, thus, were taught sufficient basics of Excel: how to enter in the constants (i.e. V_o, Θ , and g), and set the initial values of (t, x, and y). Finally, they were taught by example how to enter the equations as formulas using both relative and absolute references. Few students had difficulty with this task. To make this problem more interesting, the students were taught how to make a plot of the results.

Trebuchet Model: Several solutions for the dynamics of the trebuchet are given starting an elementary analysis, then adding a swinging counterweight, concluding the addition of the projectile initially sliding in a surface [7]. Trebuchets were 3-D printed, assembled and mailed to the students along with other project materials. While steel shot pellets were initially tried for the counter weight, rectangular lengths of steel which fit its bucket were used instead.

Armed with an idealized model, the students tested the trebuchets numerous times. They found a large variance among the trebuchets and even for a single trebuchet, typically between 0.25 m and 0.75 m. The students were asked why their experimental runs had low efficiencies. An obvious cause, friction, was obvious to all of the students. After further discussion, some suggested that the motion of masses of the moving arms and swinging of the bucket for the counter weight would also be contributing factors.

The dynamics of the trebuchet are too complicated for the students to execute on Excel. Instead, they used an on-line simulator [8]. Comparing their results with the simulator, they found large discrepancies. As a group they reflected that replicating the projectile throw was difficult because releasing the projecting when the throwing arm is at the optimum 45^o seemed to be impossible due to the design of the 3-D printout, and because the sliding of the projectile in its sling varied.

In the last part of the project the students had to program their robots to first cross the wooden bridge they previously constructed and then trigger the trebuchet to fire. Each student who tried this invented a different method of triggering which encouraged the discussion. Some tried to tie down the throwing arm with a string and cut the string with the robot, but most leaned a weight against the throwing arm to hold it and then nudge the weight with the robot causing the trebuchet to fire. Half of the students successfully managed to trigger the trebuchet.

During the discussions, the students realized that the simulations may be elementary or may include more details and hence become mathematically and computationally more difficult. The students also agreed that repeatable experimental behavior of the device required careful design and execution.

3. Civil Engineering Project

The third project is a Civil Engineering project that focused on the design and construction of a truss bridge using balsa wood and glue. The truss structure analysis is one of the important topics in the course of Engineering Statics, which is a major curriculum for students in the civil engineering, mechanical engineering, and mechatronic engineering programs at CSU Chico. Statics is the cornerstone-engineering course that requires students to synthesize and apply concepts from mathematics and physics to engineering designs of structures and machines. The specific learning objectives of this Truss Bridge project in this bootcamp were to have students apply engineering concepts (e.g. force and Newton’s laws of motion) and math skills (e.g. linear algebra and trigonometry) to analyze and design a truss bridge structure, and construct the designed truss with appropriate quality control techniques.

In this project, the topics discussed included Newton's Laws of Motion, concepts of vector and force, and resolving a force in 2D space, particle equilibrium condition, and method of joint for truss analysis, truss capacity design, and types of truss bridge (e.g. Pratt, Howe, Parker). Students practiced designing their truss bridges following the geometry design constraints that allow the robot vehicle to cross. The Balsa wood with a cross-section of 1/8"×1/8" and wood glue were used to construct the designed truss bridge. Then, students designed and installed the bridge deck using cardboard paper, and drew or taped strips on the surface of the bridge deck to guide the robot vehicle crossing the bridge on its own. Therefore, in this project, students also learned and practiced the concepts of autonomous vehicles with sensor technology and integration between vehicles and infrastructures.

One of the challenges that a few of the students had was to understand the concept of force and relate it to the project engineering concepts accordingly. Additional help and instructions were provided to those students. A total of 13 students completed both analysis and construction of the truss bridge, 2 students completed the analysis but did not finish the construction of the designed truss bridge, and 3 students did not complete the project or did not participate in the civil engineering project.

4. Electrical and Computer Engineering Project

The goal during the last three afternoons of the bootcamp was to introduce students to elements of electrical and computer engineering. The platform used for the active-learning portion of the project was, again, the Maqueen robotic vehicle. First, students were introduced to the operation of the two sensors used in autonomous navigation, the infrared (IR) sensor and the ultrasonic sensor.

On the second day, the control of systems was discussed, as this is one of the important subjects that electrical and mechanical engineering students need to learn in a 3-4 unit course. The students learned about different types of control systems such as open loop, closed loop, two position control and their applications. The concept of proportional-integral-derivative (PID) control was explained to the students. Optical sensing by encoders to measure the motor output and Pulse Width Modulation (PWM) as a way to control the speed of the DC motor was discussed. Then, the students were asked to program a PID controller for the DC motors of the robots to maintain a smoother stop, and try different coefficients for the controller to see their effects. While students were writing the PID controller codes, they looked for online resources as they had difficulty programming the project code, mostly for the integral part. They were provided with additional hints and help to proceed with completing the code. One of the challenges with having effective instructions compared to the 2019 in-person bootcamp was that the students who were not willing to reach out to the faculty or the student assistant for help, would get stuck for a while which also resulted in less engagement. In an in-person bootcamp, supervision and identifying the students that needed additional help was significantly easier. Therefore, the number of students who could complete this part of the project was lower than last year. A solution to this issue could be creating groups of two students similar to the in-person bootcamp, asking students to work with each other, and joining their Zoom breakout rooms every 15-20 minutes to see their progress.

On the third day, students designed a path for their robots to follow and developed the program that would cause the robot to complete the tasks along the path. On the final day of the bootcamp, students were expected to demonstrate the autonomous operation of their robot as it completed the course that each student designed, addressing the challenges specified by the bootcamp instructors.

During the first meeting, the physical phenomena that are employed by each sensor were discussed. In the previous year of the bootcamp, the final project required the students to rely entirely on the IR sensor and on a second visible light sensor. Hence, the discussion was focused on the investigation of optical sensing and optical phenomena in general. The 2019 bootcamp participants, then, explored the properties of light using flashlights and color filters. However, the faculty revised the final competition for the 2020 bootcamp, which meant that the IR sensor would be an appropriate choice when navigating across the bridge, but may not be the optimal choice when navigating through the rest of the course. This meant that a discussion about the properties of sensors used in autonomous navigation was needed. Again, background on the physical phenomena upon which both sensors are based was presented. Students viewed several YouTube videos, which presented the material more visually, but with no individual exploration of the phenomena. The specifications in the datasheets of the IR and ultrasonic sensor were compared to begin the discussion about the sensor selection. Because of the redesign of the final project, a conversation on how to determine when decisions on navigation should rely on IR or the ultrasonic sensor followed with examples of locations in the final project where a switch between sensors may be necessary. All but one student who completed the final project programmed the robot to use data from the IR sensor while it crossed the bridge and then employed the ultrasonic sensor to guide the robot to the trebuchet and to launch its payload.

Another aspect to autonomous navigation that was added in this year's discussion was the influence of the material properties of the object to be detected on the accuracy of the sensor output. This was critical to the success of the final project as students had to construct their own line pattern for the robot to follow as it traversed the bridge constructed during the civil engineering portion of the bootcamp. Several students discovered that the robot could not sense the line that they made. Realizing that the optical contrast between materials was not sufficient in the IR, despite the considerable contrast in visible light, these students experimented and found different materials to use to create the line.

D) Final Challenge

On the last day of the bootcamp, students demonstrated the results of the final challenge individually and competed with each other in a Zoom session while faculty were present. For the final challenge, the students had to program the robot to find its way to enter the truss bridge, cross the bridge without hitting the bridge sides, direct the robot to the trebuchet and launch its payload. While completing all these tasks was not simple, four out of the 17 students could successfully complete the challenge and win the competition. Faculty observed several innovations in the way students had the robot launch the payload. Overall, the participation of the students in the final challenge was lower than the 2019 in-person bootcamp. We are thinking about ways to celebrate the last day of the bootcamp to motivate students to participate in the challenge.

The certificates of completion were emailed to the students and the awards were mailed to the students who completed the challenge successfully.

III. Assessment of Student Success

Throughout the paper we discussed the challenges of delivering an online bootcamp, the efforts we made to address them, and our plans for the future bootcamps. The assessment of the bootcamp success includes student satisfaction with the bootcamp (formative assessment), the student success in passing the math courses that they took in Fall 2020 and student performance in ALEKS. The longitudinal study on the percentages of unsatisfactory (D) or failing (F) final course grades and course withdrawals (W) in the upper division ENGR and CS courses in addition to time-to-graduation is a work in progress.

A. Summer 2020 Bootcamp Formative Assessment

To learn about students' satisfaction with the bootcamp and their attitudes about their intended majors, we collected pre- and post-bootcamp surveys. The survey asked their attitude regarding self-efficacy using a Likert-type scale from 1 (strongly disagree) to 5 (strongly agree) on the following items:

- I am confident that I chose the major that best fits my interests and goals
- I expect to graduate with this major
- I know what skills and topics are important to my major
- I feel like I belong within the major
- I am on the right path to succeeding in the major
- I know why math is important to my major
- I can apply math appropriately in my major
- I am confident with Algebra
- I am confident with Geometry
- I am confident with Trigonometry
- I am confident with Precalculus
- I am confident with Calculus
- I enjoy math
- I can apply my math skills to computing and engineering projects

The pre- and post-bootcamp survey included the same ratings. Ten (n=10) out of seventeen students (59%) participated in the survey. The participation in surveys decreased 23 percentage points compared to the 2019 bootcamp which was held face-to-face. Table 2 shows the mean (M) and standard deviation (sd) for each item's rating.

By looking at Delta we observe that the average change in attitude represents mostly small-to-moderate increases in students' ratings of their self-efficacy from before (pre-) to after (post-) the bootcamp. Deltas are greatest for students' confidence with trigonometry (M = 1.05, sd = 0.21). and whether students are on the right path to succeeding in the major (M = 1.04, sd = 0.00).

Table 2. Summary of Likert-type scale items from pre- and post- virtual bootcamp surveys

All numbers are rounded to the nearest hundredth. Delta represents Post minus Pre response, calculated for each individual. Participants who responded to an item for Pre or Post (but not both) are included in Pre/Post column they answered, but excluded from Delta.

Statement	***Pre-Bootcamp (M,sd)***	***Post-Bootcamp (M,sd)***	***Delta (M,sd)***
I am confident that I chose the major that best fits my interests and goals	4.12, 0.70	4.3, 0.67	0.47, 0.07
I expect to graduate with this major	4.31, 0.79	4.20, 1.23	0.47, 0.07
I know what skills and topics are important to my major	3.71, 0.92	3.80, 0.79	0.91, 0.29
I feel like I belong within the major	4.24, 0.66	4.00, 0.67	0.53, 0.14
I am on the right path to succeeding in the major	4.00, 0.79	4.00, 0.82	1.04, 0.00
I know why math is important to my major	4.53, 0.62	4.7, 0.48	0.39, 0.00
I can apply math appropriately in my major	3.94, 0.83	4.00, 1.05	0.47, -0.07
I am confident with Algebra	4.59, 0.71	4.9, 0.32	0.61, 0.29
I am confident with Geometry	4.41, 0.62	4.40, 0.52	0.94, 0.57
I am confident with Trigonometry	3.65, 0.70	3.90, 0.88	1.05, 0.21
I am confident with Pre-calculus	3.76, 0.83	4.10, 0.74	0.58, 0.21
I am confident with Calculus	3.12, 1.32	3.6, 1.51	0.77, 0.14
I enjoy math	4.24, 1.09	4.00, 1.25	0.47, -0.07
I can apply my math skills to computing and engineering projects	3.88, 0.78	4.10, 0.74	0.47, -0.07

Since the number of students who responded to the survey was low, we do not draw significant conclusions from the survey results. However, we will keep looking into innovative ways of engaging students during online bootcamps.

There were decreases in the sense of belonging to the major and in student enjoyment of math in the online bootcamp whereas in the in-person Summer 2019 bootcamp, there were increases in both of the responses. This could be having online math sessions in Zoom which are clearly less engaging than in-person sessions. We are going to break the three hour math sessions to two 1.5 hour sessions, and have the math tutor provide the students one problem outside ALEKS to engage the students more. The decreased sense of belonging to the major could also be due to the fact that the students had to do the projects individually. This makes the projects more challenging and difficult for the students and consequently decreases the sense of belonging to the major.

The post-bootcamp survey also included six questions to rate the morning ALEKS math tutorials and the afternoon engineering projects. The questions used the same five-point Likert-type scale to evaluate the bootcamp activities on how *fun*, *challenging*, the activities were designed and how much they *learned* from either activity. Figure 1 illustrates the responses.

Participants responded that the math tutorials were *fun* (M = 3.00, sd = 1.05) and *challenging* (M = 2.60, sd = 1.07) and agreed that they *learned* from the math tutorials (M = 3.90, sd = 1.20). They believed that the engineering projects were more *fun* than the math tutorials (M = 4.20, sd = 0.79) and *challenging* (M = 4.10, sd = 0.99) and *learned* from the projects (M = 4.30, sd = 1.06).

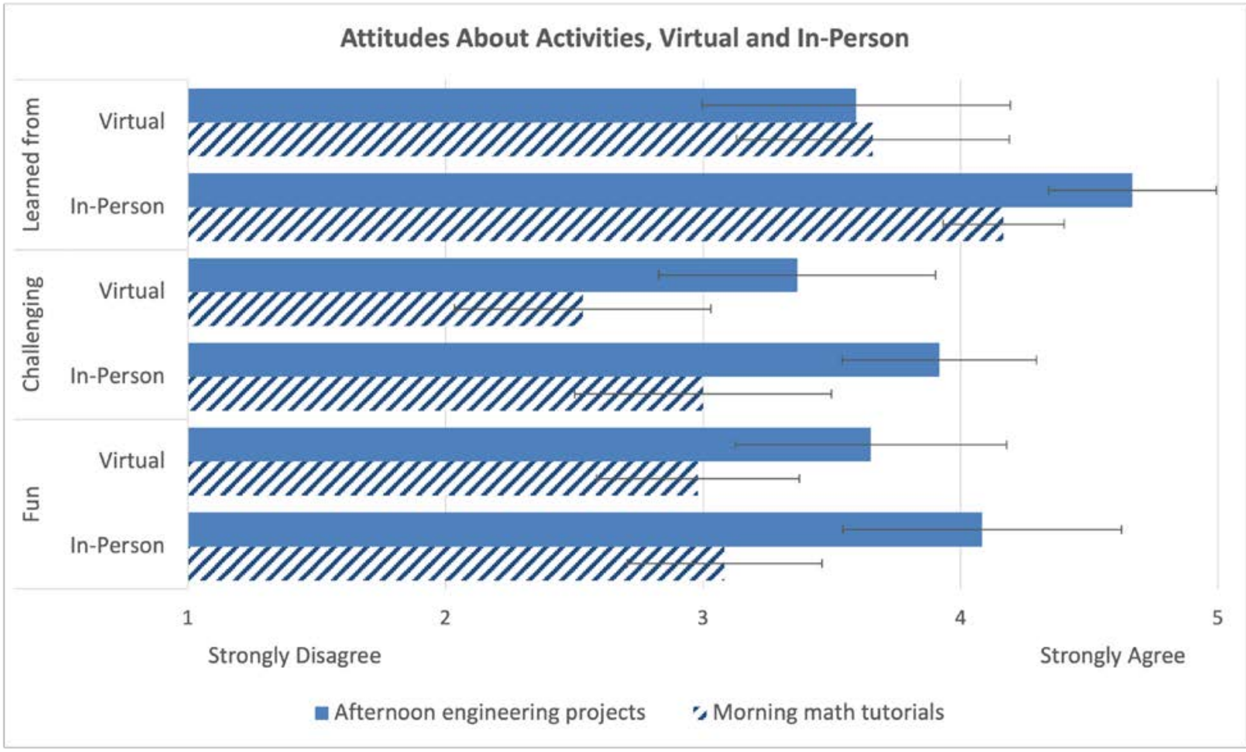

Figure 1. Bar chart showing the mean Likert-scale rating (with standard deviation bars) of students' perspectives of the bootcamp activities.

In response to "How could have the bootcamp been improved?" participants responded that more interactive math sessions would be helpful, as well as shorter math sessions and shorter project sessions. We plan to address these recommendations in the future bootcamps by alternating between math and project sessions during the day, rather than longer morning/afternoon periods of focusing on only math problems *or* project sessions.

B. Assessment of student learning through ALEKS

On the first day of the online bootcamp math sessions, students took the initial knowledge test of the ALEKS STEM Pre-calculus course while a student mentor was available in Zoom to help the students. The ALEKS software provides the percentage that each student mastered at the end of the knowledge check. Table 3 demonstrates the summary of participants' scores at the initial knowledge test and after completing the three week math course. Evidently, the scores of students increased after the three week bootcamp as a consequence of solving several problems for each course topic (total of 325 topics). One student completed the course with a grade of 100% during the second week, and started the advanced STEM Precalculus course. The students who had a slower progress and increase in the percentage of completed topics were contacted by the faculty and Math tutor frequently. Additional help and resources were recommended to those students. Additional techniques need to be used to engage students more and increase the Final ALEKS percentage for each student. Making the math sessions shorter but with more frequency during the day could help students to stay engaged.

Table 3. Summary of students' knowledge assessments before and after the completion of ALEKS STEM Precalculus course

Student Number	*Initial Knowledge Check Mastered (%)*	*Final ALEKS Pre-calculus course Assessment grade (%)*	*Improvement (%) Online 2020 Bootcamp*
1	38%	54%	16%
2	62%	85%	23%
3	69%	78%	9%
4	58%	74%	16%
5	64%	100%	36%
6	57%	63%	6%
7	81%	91%	10%
8	87%	97%	10%
9	28%	61%	33%
10	57%	72%	15%
11	53%	89%	36%
12	38%	73%	45%
13	39%	72%	33%
14	46%	58%	12%
15	30%	70%	40%
16	59%	77%	18%
17	11%	34%	23%

C. Fall 2020 Post-Bootcamp Assessment

A summary of students' grades at the end of Fall 2020 has been tabulated in Table 4. Four out of the seventeen bootcamp participants were transfer students who had passed the required math courses and did not enroll in calculus or its prerequisite in Fall 2020. Two of the participants took the Foundational Mathematics A as a credit course and will be taking the College Algebra, Trigonometry, and Precalculus during the next semesters. Compared to the 2019 bootcamp, we did not have any students who withdrew from all courses or students who did not enroll in any of the math courses which would delay their graduation. Similar to the 2019 bootcamp, 10 out of the 11 (90.9%) remaining students passed the math course in which they enrolled in the Fall 2020.

The students were encouraged to continue using their ALEKS accounts after the bootcamp as the codes were valid until the end of Fall 2020. They were also encouraged to inform the bootcamp coordinator if they needed an extension of their accounts.

Table 4. Summary of students' progress in math courses at the end of Fall 2020 semester

	Number of Students	Percentage of Bootcamp Participants
Participants in Summer 2020 bootcamp	17	100%
Transfer students who had previously passed required math courses	4 of 17	23.53%
Enrolled in Foundational Mathematics A (MATH 031B) as credit (CR)	2 of 17	11.76%
Passed the Fall 2020 math courses if they had enrolled in one course	10 of 17	58.8%
Failed the Fall 2020 math courses if they had enrolled in one course	1 of 17	5.8%
Passed Trigonometry (MATH 118)	1 of 2	50%
Passed Pre-calculus (MATH 119)	6 of 6	100%
Passed Analytic Geometry and Calculus (MATH 120)	4 of 4	100%

D. Future Work

a. Summer 2021 Bootcamp

We are planning to hold the online bootcamp again during the Summer 2021. Funding provided by the Office of Undergraduate Education and College of ECC will enable up to 25 students to participate in the Summer 2021online bootcamp. Faculty are also working with the College of ECC to continue the bootcamp over the next years and expand the number of students who can participate in the bootcamps.

b. Assessment

The longitudinal assessment of the bootcamp will be carried out by faculty assessing the performance of the students in math courses as well as the higher division courses using their progress to degrees, retention, and the number of years it will take each student to graduate. This longitudinal assessment of the bootcamp is a work-in-progress. We anticipate that the knowledge that students gain through the ALEKS learning tool, will help them to decrease the time-to-graduation one to two semesters. Since the number of the bootcamp participants is small, multiple offerings of the bootcamp will provide a more promising statistical data.

IV. Outcomes

The recruiting process has been a challenge since many of the students are not aware of the importance of the math courses in engineering majors or are not interested in spending part of their summer on practicing math. For the next bootcamp, the Student Success Center of the College has been promoting the bootcamp to the incoming students to help with the recruiting. Through the online bootcamp, students practiced Precalculus math and were engaged in engineering projects. The challenges that we faced due to the online delivery of this bootcamp were the lower engagement level of the students in math sessions and engineering projects compared to the in-person bootcamp. The mentioned challenge would be addressed in our next bootcamp by splitting the math and engineering sessions into shorter sessions, designing math problems outside ALEKS to engage all the students at the same time in solving those problems. Techniques of student engagement in the engineering projects will be sought to keep students motivated and interested in the projects as well as the final challenge.

V. Conclusion

The Math and Engineering bootcamp was held with few differences in Summer 2020. First, due to the COVID-19 pandemic, the bootcamp was held exclusively online and in Zoom sessions. The required materials for the projects were shipped to the students prior to the bootcamp. The students joined the Zoom meetings every morning and afternoon, four days a week, to practice math problems in the Pre-calculus level and do hands-on engineering and computer science projects. Second, the Civil Engineering major was added to the majors that were presented to the students. The third difference was adding a final challenge that was designed to integrate the abilities that students gained through all four projects that were carried out during the bootcamp afternoon sessions. The transition to an online bootcamp was done successfully and the students were well engaged in the projects. However, further improvements can be made to engage students more. The paper discussed the challenges of the math tutorials and each of the projects, discussed the efforts that were made to address them, and made recommendations for future bootcamps. The Fall 2020 grades indicated that 10 out of 11 (90.9%) of the students who took the pre-requisites of calculus passed them successfully confirming the effectiveness of the math sessions in increasing students' knowledge and skills. Longitudinal studies will be implemented to determine the effectiveness of the bootcamp in the time-to-graduation of the participants compared to other students in ENGR and CS departments. We will be looking into ways to make the math sessions more interactive, engaging and fun.

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