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Work-in-Progress: Project-based Learning in a Summer Engineering Program Implemented Virtually

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Dr. Jingbo Louise Liu received her Ph.D. in Materials Science and Engineering from the University of Science and Technology Beijing in 2001. She was promoted to a tenured Full Professor at Texas A&M University-Kingsville (TAMUK) due to her outstanding creativity and productivity for nanostructured materials preparation, characterization, and understanding of fundamental physical and chemical properties of nanoparticles, nanofilms, and nanotubes, as well as applications of engineered nanomaterials in alternative energy and biological science. She established the highest power density to advance the performance of proton exchange membrane fuel cells and directed a new paradigm to apply metal-organic frameworks in disinfection science. Dr. Liu has authored and co-authored textbooks (4), books (6+2) and book chapters (>15) and over 80 peer-reviewed journal articles. She chaired and organized international conferences and presented more than 100 talks in professional conferences. She has been hosting and co-hosting 10 visiting scholars to conduct leading-edge research on biomedicine, hydrogen fuel cells, photocatalysis and nanotechnology. During 15.5-year services in TAMUK, she taught about 10,700 students; trained more than 150 undergraduate students, 40 master students.

She served as NSF panelist and Chaired the proposal review panel. She also served as Journal Editor and reviewed hundreds of peer-reviewed journal papers. Currently, Dr. Liu serves as the Immediate Past Chair of Energy and Fuels Division of American Chemical Society and Officer at the Sigma Xi, The Scientific Research Honor Society (TAMU Chapter). She has been elected as Fellow of the International Association of Advanced Materials (FIAAM), Fellow of Vebleo (Science Engineering and Technology), and the Fellow of the Royal Society of Chemistry, DEBI faculty fellow at the US Air Force Research Laboratory. She has been awarded the Chartered Scientist and Chartered Chemist in March and May 2019, respectively. She was awarded the “2012 to 2014 Annual foreign experts and talent from overseas project” supported by the State Administration of Foreign Experts Affairs, P.R. China (3 consecutive terms); Japan Society for the Promotion of Science (JSPS) Invitation Fellow and worked at the Department of Materials Science, University of Tokyo (2010-2011). She has served as a “Faculty and Student Team” fellow, collectively funded by the National Science Foundation and US Department of Energy, Office of Science and worked at the Argonne National Laboratory (2009). She also received Faculty Fellowship Summer Institute in Israel (2008) and outstanding research and teaching awards at the university level. She directed and participated in the projects (> 40) supported by the NSF (USA, CHINA), NSERC (CANADA), American Chemical Society Petroleum Research Funds (PRF), R. Welch Foundation (departmental grants since 2006), Department of Education, industrial and TAMUK as PI, Co-PI and senior personnel. She also received dozens of travel funds to attend QEM Workshops; NIH Faculty Grant Writing Workshop; Higher Education Consortium Workshop, Universities Space Research Association; and COACh (NSF women advancement) workshops.

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Mahesh Hosur

Work-in-Progress: Project-based Learning in a Summer Engineering Program Implemented Virtually

Introduction

Faculty with the College of Engineering (COE) at Texas A&M University-Kingsville (TAMUK) implemented a first-year virtual Summer Bridge Program (SBP) in 2020, as part of an NSF Improving Undergraduate STEM Education (IUSE) grant. This paper discusses the second year of the SBP, which was held virtually in summer 2021. Two faculty from College of Arts and Sciences were added to the SBP in this second year. The SBP objective is to increase motivation of student's academic performance, and increase retention using high impact enrichment (project-type) activities. The program enrolled underclassmen from the TAMUK COE and potential engineering transfer students from nearby community colleges and universities. Extracurricular Bridging Programs identified as a student success strategy by other engineering colleges served as an impetus for the SBP in an NSF IUSE grant [1-3]. The intent of this paper is to share the results of the second annual virtual SBP in the NSF IUSE grant at TAMUK, and to inform and solicit feedback from other undergraduate engineering education experts.

Texas A&M University-Kingsville is located in south Texas, an area where Hispanic/Latinx populations are the majority [4]. TAMUK is an Hispanic-serving institution (HSI) and has a student population that is majority Hispanic/Latinx, specifically 75% Hispanic/Latinx as of fall 2020 [5]. Higher education research has identified challenges for Hispanic students at all levels, community colleges [6, 7], universities [8, 9], and in graduate study [10, 11]. Challenges such as academic deficiencies, lack of cultural support, poor sense of belonging, and lack of faculty support also exist specifically for Latinx students at TAMUK, based on recent research [12], which serves as a secondary impetus for the implementation of the SBP.

Helping participants to identify as engineering students, which has been shown to impact student retention positively, was a third impetus of the SBP [13-15]. The SBP program was planned to address Latinx student challenges, thereby improving identity as a student engineer and building upon the existing research for summer programs in STEM fields. For the summer 2021 SBP, 50 students were enrolled.

Program Implementation

The 2021 SBP program consisted of a virtual 2-hour session held each weekday for a period of three weeks in July. Both the first and second offerings of the SBP were held virtually due to COVID-19 conditions prevalent at the time. A Zoom platform was used to conduct the virtual meeting of the second SBP. A weekly stipend, paid after the fact, was provided to each participant as an incentive for continued attendance. The content of the SBP program included a mix of engineering presentations by TAMUK faculty in engineering or closely related STEM fields (math and chemistry), guest presentations by working engineers, and high impact projects. Participants were assigned to discipline-specific teams so that group activities aligned with students' interests or current declared engineering major. Discipline specific cohorts were Chemical and Environmental Engineering, Civil and Architectural

Engineering, Electrical Engineering and Computer Science, Mechanical and Industrial Engineering, and Industrial Technology.

The faculty lectures discussed the engineering design process; importance of mathematics, chemistry and computers in engineering; engineering mechanics; data analysis; public safety; ethics; professional licensure; and career searches. Content varied from material that would be included in freshmen engineering courses to material that introduced advanced (upper-level) engineering courses. The portion of the SBP program involving industry professionals as guest speakers consisted of three panel discussions and three stand-alone presentations. The three panel discussions invited guests from different career stages as follows: (a) early career professionals, (b) a recent winning senior design team from Computer Science in TAMUK's COE, and (c) seasoned engineers. Each panel had four to five speakers. With stand-alone presentations and panel discussions, 17 industry professionals participated in the SBP, ten of whom were Hispanic/Latinx and seven of whom were female, two categories of individuals who are underrepresented in engineering [16, 17]. With a high percentage of participants being female (38%) and Hispanic (62%), guest speaker diversity was a program priority, so that SBP participants could understand that gender and ethnicity should not be a hindrance to becoming successful engineers.

Design-related Activities

Two primary experiential learning activities incorporated into the SBP were a short (1-day only) engineering challenge and an engineering or technical design project carried out over the majority of the program. Experiential learning activities were selected by the faculty to introduce participants to engineering problem-solving. In addition, the design project activity exposed participants to engineering concepts they will encounter in junior and senior level courses both as an intellectual/academic challenge and preparation for upper-level coursework. Both experiential learning activities were organized by discipline specific cohorts.

The short, 1-day engineering challenges were completed on the second day of the SBP and are summarized in Table 1. Most activities were adapted from IEEE's Try Engineering activities [18]; the base isolation activity was adapted from a Science Buddies [19] activity. Since the SBP was implemented virtually, kits containing necessary materials were mailed to each student the week before the program began.

Table 1. 1-Day Engineering Challenge Activities

Cohort	**Groups**	**Challenge**	**Objective**
Civil and Architectural	2	Base Isolation: Creating Earthquake Resistant Structures	Students experimented with damping materials (markers, erasers, cotton balls, etc.) to reduce acceleration on a food storage container "house."
Chemical	2	Toxic Popcorn	Students tasked with removing 'toxic' container without touching it directly.

Electrical and Computer Science	2	Cartographer's Dilemma	Students color a segmented map without allowing common borders to have the same color.
Mechanical I	4	Marshmallow	Students challenged to construct a tall structure using marshmallows and spaghetti.
Mechanical II	2	Tall Tower	Students challenged to construct a tall structure to hold a golf ball using only straws, paper clips, and pipe cleaners.

The engineering design projects that were assigned to the student teams, consisting of three to six student participants each, over the last 2½ weeks of the program included (a) municipal water supply system design for two Chemical and Environmental Engineering groups, (b) app-based game programming for two Electrical Engineering and Computer Science groups, (c) design of a truss bridge for two Civil and Architectural Engineering groups, (d) plastic part design and 3-D printing for two Mechanical and Industrial Engineering and Industrial Technology groups, (e) atomic crystal structure analysis for two additional Mechanical, Industrial Engineering, and Industrial Technology groups, and (f) finally one group each for hydrogen fuel cell car design and for engineering optimization. All teams gave a presentation of their project work and submitted a final report on the final day of the SBP. Design project descriptions for new projects in the second-year offering are provided below. Design project descriptions for projects repeated from the first-year offering (groups from Electrical Engineering and Computer Science, Civil and Architectural Engineering, and the first set of Mechanical and Industrial Engineering and Industrial Technology) are provided in a prior publication [20]. The projects described there are those listed as items b, c, and d above

The Chemical and Environmental Engineering cohort included two student teams that performed the pipe network design required for a small-town potable water distribution system. Each team calculated the total water supply required for a small town based upon water demands per person per day, population size chosen by students, and a minimal industrial demand. The instructor then provided basic fluids equations that the students used to estimate head pressure needed in an overhead water storage tank serving the town, and the pressure losses attributable to water flowing out to a variety of end-use points. The objective of this mini-design project was to provide the students with some experience in mass balance applications, fluid energy, and pressure loss concepts. The participants located relevant information from sources such as the Texas Water Development Board website, the online source Engineering Toolbox, and various technical articles and how-to websites for engineering.

The second Mechanical Engineering cohort project studied and developed a model of the cubic crystal structure of a diamond. Students were taught about the fundamentals of crystallography and X-ray diffraction. They also learned about how to calculate the distance between the atoms based on various crystal structures and different types of bonds such as Van der Waals, ionic and covalent bonds. They were instructed about how the crystal structure of a material is deduced based on the X-ray diffraction information. Furthermore, after learning the fundamentals of crystallography, students were asked to build the diamond cubic crystal structure using the items sent to them. Students appreciated learning fundamentals of crystallography which enhanced their understanding of matter in terms of crystal structures and its properties.

A cohort of mechanical engineering students studied hydrogen fuel cell-driven vehicles (HFCV), that utilize H_2 as a fuel source without generating greenhouse gas emissions. Currently, HFCV development and deployment encounters problems due to limitations of H_2 availability and manufacturing costs. Different strategies have been investigated to overcome the above issues, including on-board hydrogen production and utilization. This activity showed that water electrolysis can produce green hydrogen which can be used as fuel supply to generate direct electricity for portable and stationary applications. A group of students were trained to assemble the HFC model car and test its "on-road" operational performance under ambient conditions. The model car illustrates the capacity of green hydrogen production and "mileage" per liter of water. Through these efforts, students gained core-knowledge of chemistry, chemical engineering, and materials sciences, which opens a door for them to explore STEM study with a focus on innovation for car designers in the future.

A cohort of electrical and computer science students worked on an engineering optimization problem seeking the shortest path from a starting point to an ending point. In this project, given any location of a monkey and a banana on a 50x50 grid, under some constrictions for how the monkey could move, the students worked to find the shortest path to get the banana. Participants completed a literature review on the applications of optimization problems in engineering to increase their understanding to solve an optimization problem using Matlab. The problem was solved by constructing a target function, finding the constricted condition, and Matlab programming. The intention was to provide a practical problem-solving and coding experience.

Results

All project participants were asked to complete a pre- and post-participation survey in both years of programming. Outcomes from the summer of 2020 have been discussed in a prior publication [20]. The surveys sought insight into the backgrounds of the students and responses that would allow assessment of the impact of the programming. The intent was to ascertain whether participation resulted in perceived increases in student understanding and skill and awareness of and interest in engineering and whether impacts differed for subsets of participants. Twenty-one queries for pre- and post-participation surveys were developed from instructional purpose and learning objective statements submitted by the participating faculty in 2020. Adjustments to programming were made for 2021 based on the faculty and students' experiences in the pilot program. This involved addition of material about chemistry and ethics in engineering. Thus, the 2021 version of the survey had 25 questions. This paper describes the 2021 programming and outcomes with 2020 assessment process and outcomes information provided to support conclusions drawn.

In 2020, a total of 37 persons enrolled in the online summer program, 18 of whom identified as females and 19 who identified as males. Twenty-seven of them considered themselves to be Hispanic/Latinx, while the remaining ten classified themselves as non-Hispanic. The Hispanic students conceived of their racial identity predominantly as Hispanic/Latinx (n = 22), but four saw themselves as White and three others as both Hispanic/Latinx and White (one did not respond to this query). Non-Hispanics were predominantly White (n = 7), with three African Americans, one of whom also identified as Asian [20]. In 2021, 49 of 50 participants responded. There were 16 females and 31 males. Two students did not respond to the question. Thirty of these individuals identified as Hispanic/Latinx and 17 as non-Hispanic (two did not respond). Four considered themselves to be African American, eight Asian, one Hawaiian/Pacific Islander, 25 Hispanic/Latinx, one Native American/Alaska Native, and 11 White (total count exceeds 49 as informants were allowed to select all racial categories they felt applied). In both years, the patterns were similar to the institution's overall student population which is 75% Hispanic, 4.6% African American, and 15% White, with a gender ratio shifted slightly toward males (52.7% to 47.3% female).

Nearly two-thirds of the 2020 informants, 23 out of 37 (62.2%), were first-generation college students (defined in the question as "neither of my parents/guardians possesses a college degree") [20]. The percentage was slightly lower for 2021 participants, 27 first-generation college students (55.1%), 18 who were not, one who did not know, and three who did not respond.

In 2020, 23 of 37 students, and in 2021, 24 of 49 summer bridge program participants felt their math skills were "above average" in comparison to their classmates or "average" (n = 11 in 2020 and 16 in 2021) (Figure 1). Most of the remainder felt they were "in the highest 10%" (n = 3 in 2020 and n = 7 in 2021), but two felt they were "below average" in 2021. Thus, most of the students should have been well positioned for the mathematical content in the SBP.

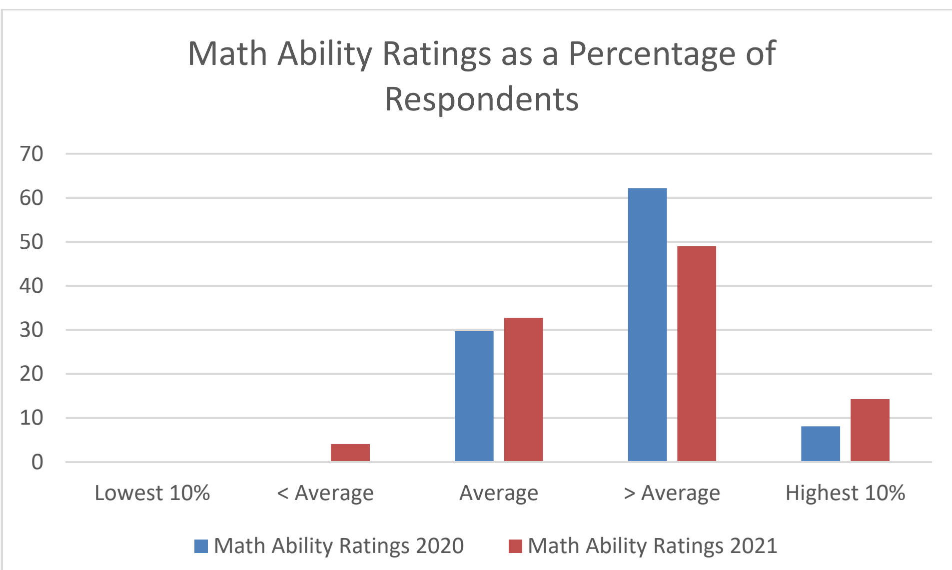

Figure 1

The volume of Advanced Placement and dual enrollment experience in the cohorts provided further support of academic preparation (Figure 2). Nineteen of the participants reported having taken Advanced Placement (AP) classes in 2020, 16 reported completion of dual enrollment classes (11 of these had also taken AP classes), and 12 indicated that they had not taken AP or dual enrollment courses [20]. In 2021, the counts were 26 with AP credit, 18 with dual enrollment credits (14 who also had AP credits), and 17 who had not taken AP or dual enrollment courses.

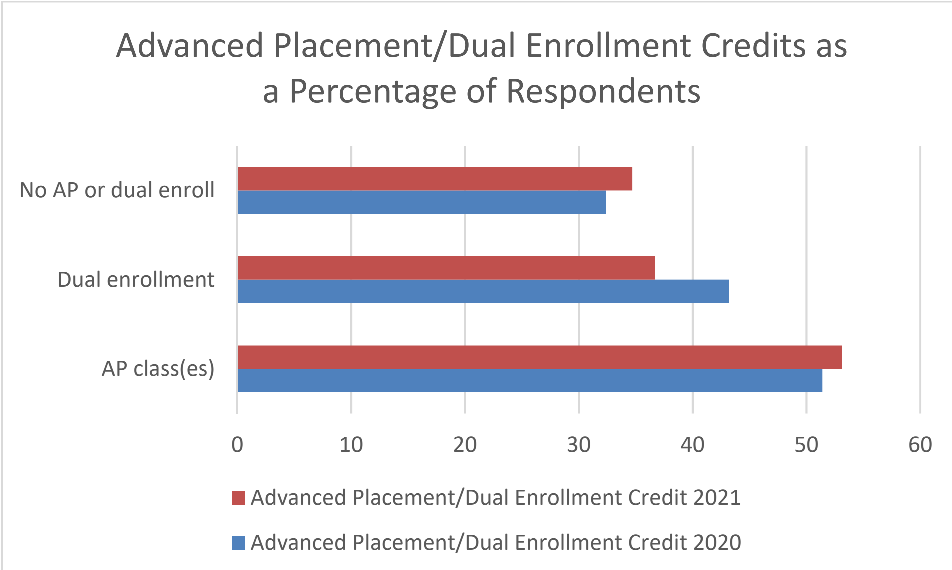

Figure 2

There was strong but not 100% participation in the pre- and post-participation surveys. Of the 37 2020 summer program participants, 36 accessed the pre-participation survey. Of them, one was under the age of 18 and not permitted to submit responses, three completed the informed consent questions but did not submit responses to the other queries, and two others provided responses but infrequently [20]. In 2021, 49 of the 50 participants accessed the pre-participation survey. One of them did not proceed past the informed consent questions, leaving a total of 48 respondents, but as many as ten of them did not respond to some questions. Respondent counts, then, for the pre-participation surveys varied from 28 up to 33 by question in 2020 and from 38 to 46 in 2021.

All 37 participants completed the post-participation survey in 2020. The one student who had been under the age of 18 prior to the summer program celebrated a birthday during it and was able to submit post-participation responses. Like the pre-participation submissions, some individuals elected to not answer several questions. The respondent counts were either 35, 36, or 37 for the 2020 post-participation survey queries [20]. The 2021 cohort had 49 submissions for the post-participation survey, although one was nearly blank, and none of the questions had answers from all informants. The respondent counts occurred in a narrow range of 45 to 47. Statistical analysis in both years took the response patterns into account.

The pre-participation responses facilitated a consideration of the knowledge base of the CC transfer students in the summer bridge program as the students were asked to rate their level of experience in 21 areas in 2020 and 25 in 2021. A ten-point scale was used and informants were instructed to submit a rating of zero for "no experience/ability" and a rating of ten for being "well informed/very capable" in the area. The responses facilitated a rank ordering of ratings by topic, with the highest mean as the primary sort and standard deviation (lowest) and then mode (highest) as tie breakers. In 2020, the responses occurred in five groups based on natural breaks in the values for the groups' numeric average. The evaluator assigned group titles which are listed here from most to least common: (1) general computer skills, (2) introductory exposure, (3) basic patterns of differentiation and application, (4) intermediate application of knowledge, (5) specific skill sets, and (6) cross-cutting systems or synthesis [20]. The 2021 responses were notably different than those submitted by the 2020 cohort members.

In 2021, the participants were more confident in their background in the areas surveyed. All but one of the means for the prompts was higher than in 2020; the top three means in 2021 were higher in value than the highest mean in 2020; 2020 responses had three means above the value six on a ten-point scale while 2021 had nine; 2021 values had fewer natural breaks in the ranking (more items in which the respondents had similar levels of confidence); and all the 2021 means were above 3.36, while three in 2020 were below that value. The higher level of confidence in 2021 and clumping rather than differentiating experience across topic areas suggests a different background for the participants, although it may also have been a group with higher but unfounded confidence. Participant background has institutional implications relevant to integrating transfer students into study which will not be discussed herein but it also has implications when interpreting the survey data.

Wilcox Wilcoxon analysis was employed for the 2020 data. The 2021 data set was analyzed using a paired-sample *t* test and a randomized test. The randomized test was applied as there were significant deviations from normality for some items in the 2021 data and randomized tests do not assume normality.

In 2020, the means for agreement with the statements increased markedly for every item on the survey pre- to post-participation and all the increases were highly statistically significant [20] (Table A in the Appendix). One significance value was $p = .001$, for ability to explain the use of 3D modeling software in engineering, and all others were $p < .001$. The clear indication was that the educational programming was effective in altering students' understanding, even in areas in which they felt they had a good understanding prior to participating [20]. The 2021 responses followed the same pattern (Figures 3, 4, and 5) even though the participants that summer were more confident in their abilities when entering the program. All queries had p values of $< .001$ when comparing post-participation to pre-participation submissions (Table A in Appendix). Outcomes for 2020 are not graphed as the focus herein is results from 2021 programming. Were they to be, the representation would parallel Figures 3, 4, and 5 but with larger differences pre- to post-participation.

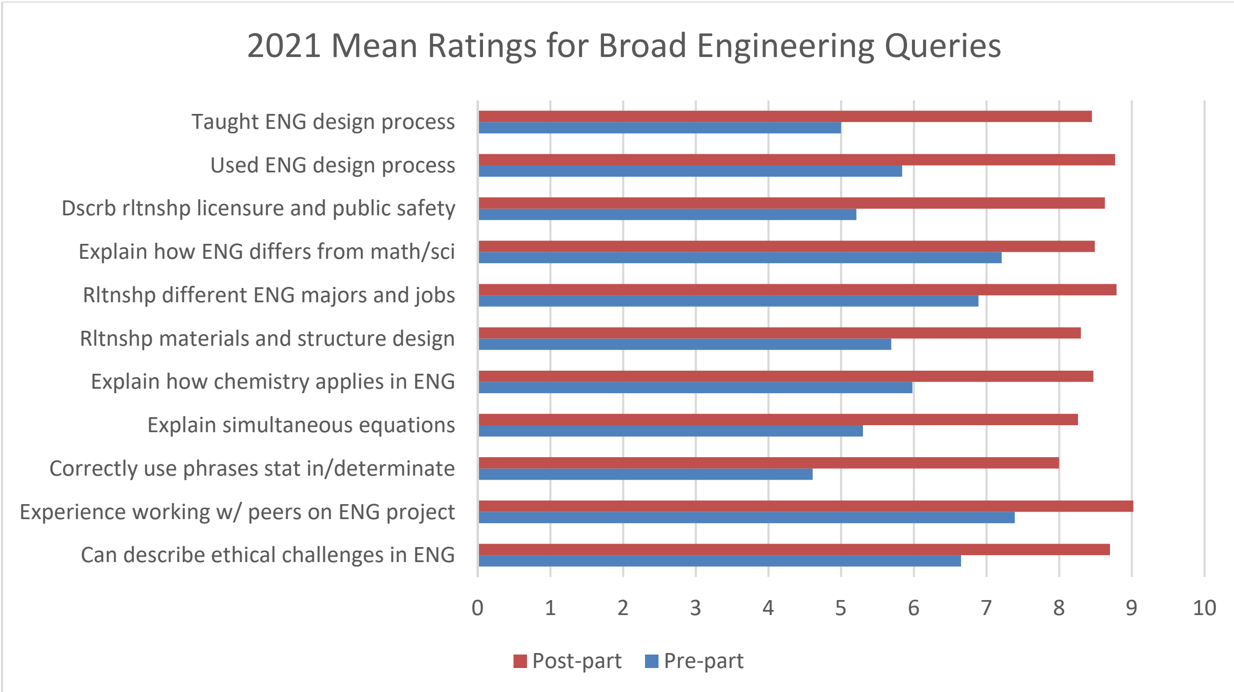

Figure 3

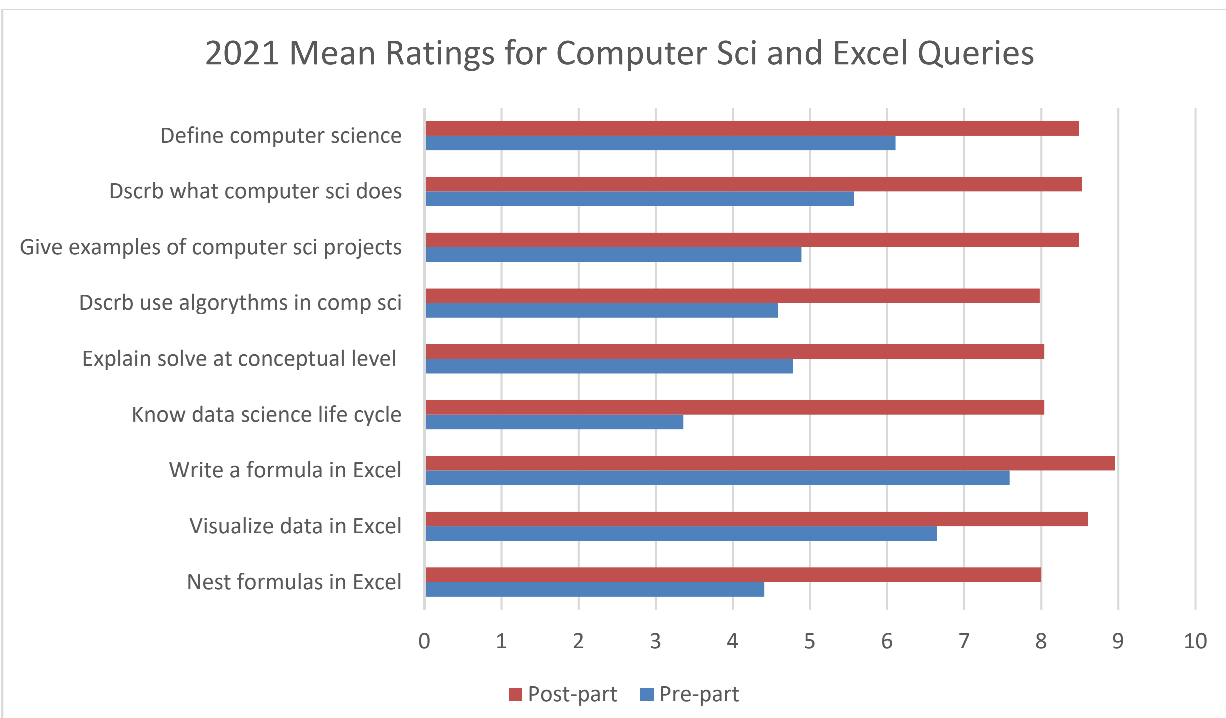

Figure 4

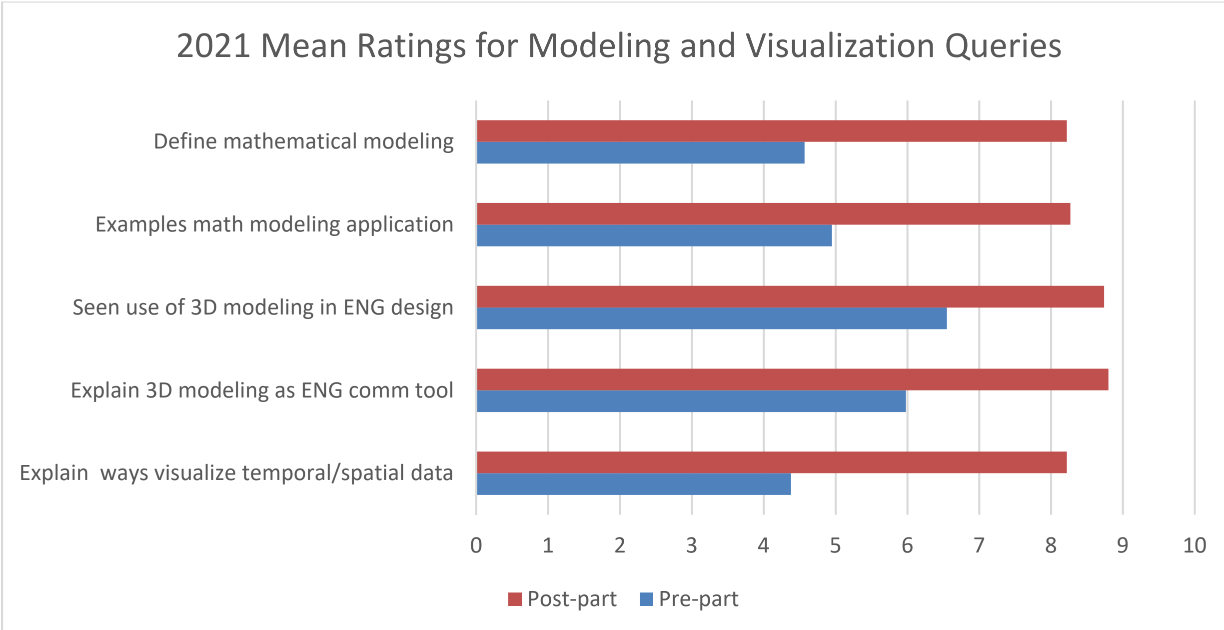

Figure 5

The uniform and statistically significant responses regarding ability and understanding are important. They demonstrate the programming was an effective educational tool. This was the case even though it was offered online and to individuals who were predominantly from underrepresented populations, many of whom were also first-generation college students. The supposition that the summer programming was efficacious is supported by responses to the first question asked on the post-participation survey. That was "What is your overall rating of the online programming you participated in this summer?" In 2020, thirty-six of the 37 respondents submitted responses on a five-point Likert scale (Poor to Excellent). There were two responses of Good, nine of Very Good, and the remaining 25 were Excellent [20]. In 2021, 47 of 49 informants submitted responses, with 28 choosing Excellent as their rating, 13 Very Good, 4 Good, and 2 Fair.

Results: awareness of and interest in engineering

Three other objectives of the summer activity were addressed on the post-participation survey. These were increasing awareness of opportunities in engineering, increasing interest in engineering, and contributing information relevant to career decisions. The questions for these topic areas were: (1) "The presentations and activities increased my awareness of the variety of opportunities available to people who study engineering." (2) "The presentations and activities increased my interest in studying engineering." And, (3) "The presentations and activities helped me refine my career goals." [20].

Students were asked to provide a rating between zero (0) and ten (10) for each statement. They were instructed that zero indicated "no impact" and ten "a very large change." One student did not respond to this set of three questions in 2020 and two did not in 2021.

The mode response for each question in 2020 was the highest possible score, ten. The numerical average was 8.83 for increasing awareness, 8.69 for increasing interest, and 8.46 for assistance refining career goals (Figure 6). These are very positive outcomes, although it should be noted that the standard deviations for ratings approached or exceeded the value two, 1.84, 1.91 and 2.37 respectively, which indicates variation in student experience. The range of ratings in 2020, one to ten, illustrated this and may have resulted from a number of factors including prior experience and understanding on the part of the participants. For example, a student with substantial prior experience or a firm commitment to a specific career path may not be strongly swayed to consider other options by a three-week, online education offering [20]. Yet, as illustrated in Figure 6, low ratings were limited. In fact, all the ratings of one were submitted by the same party in 2020 and should, as a result, be considered to represent an unusual situation if not as outliers.

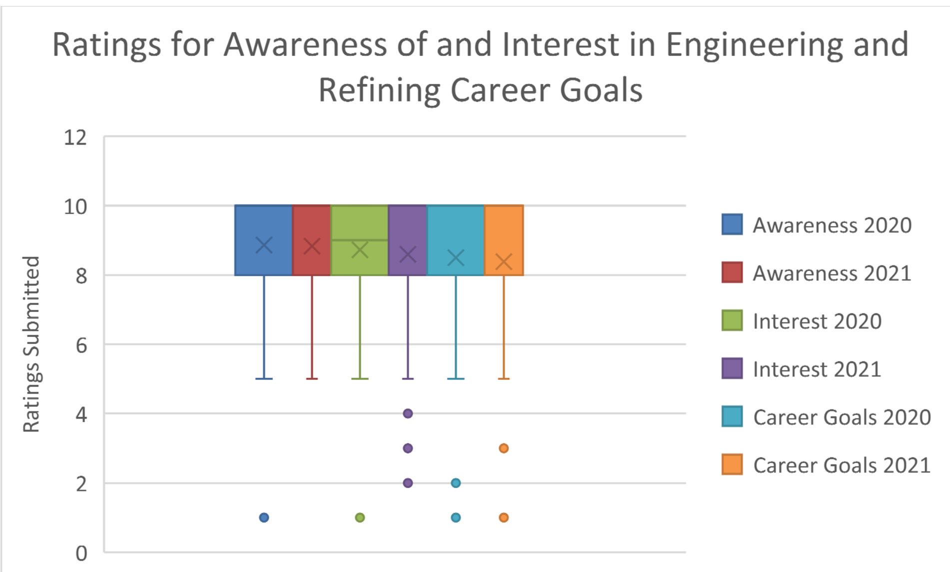

Figure 6

The 2021 responses had means similar to those 2020: 8.83 for increasing awareness, 8.60 for increasing interest, and 8.38 for assistance refining career goals (Figure 6). The standard deviations were also similar to those for 2020, 1.60, 2.03, and 2.33 respectively, while the mode for each question was again the highest possible score. These responses confirm the 2020 finding that, from a student participant perspective, the programming increased awareness of opportunities in the field of engineering, interest in studying engineering, and helped students refine their career goals, although the final item had the widest variance in responses.

Three open-ended questions were included in the post-participation survey. These asked what the informant considered to be the "most valuable form of learning in the summer program," "the most valuable activity," and whether the student had any other comments to share with the project team and faculty members [20]. Open coding of the 2020 and 2021 submissions [21] for the first question resulted in ten primary themes for the most valuable form of learning.

- Multiple perspectives shared regarding work experiences and careers.
- Information about the variety of opportunities in engineering fields.

- Information provided by guest speakers about their experiences.
- Information about engineering ethics.
- An opportunity to work on a team in a group project.
- Learning to use software applications.
- Interacting with and being able to ask questions of engineers.
- Learning from peers.
- Learning from group project mentors.
- Understanding opportunities exist for females in engineering.

The query about the most valuable activity elicited a broad range of replies including a response that the entire "program [was] extremely valuable and informative" from a 2020 cohort member and "Every activity and class as a whole…[and] all classes left me great experiences" from a 2021 participant. The most common specific response was that the group activity had been most valuable. While there was general attribution of value for the programming and one item frequently noted, the variety in comments indicated variation in perceived value. This is likely related to personal background and varied levels of experience or interest in respect to the topics covered in the faculty and guest presentations and/or the group projects. Overall, these comments affirm that the material covered was broad but proved effective [20].

The final question was: "Is there anything else you would like the project team and faculty members to know about your experience this summer?" The responses were primarily expressions of praise and thankfulness. Students in both years noted that gaining familiarity with personnel at the university made them more likely to consider it as their next stop in higher education.

Conclusions and Future Direction

The ability to have a strong and positive impact on student understanding in areas foundational to success in engineering study shown by the SBP is valuable. Having the same level of impact with two groups, one of which was more confident at entry, a year apart substantiates the educational efficacy of the process. That the two groups were comprised mostly of individuals identifying with underrepresented groups (~70%) many of whom where first-generation college students (58.1%) is also noteworthy as is the relatively high percentage of female participants (39.5%). The consistently positive outcomes reported indicate the programming offered proved efficacious for all parties and comparisons based in ethnicity and gender identity support this conclusion. The only caveat is that all but two of the participants felt they had average or above average math skills and many had completed AP or dual enrollment courses. It is possible that outcomes for parties with lower levels of mathematical and advance course experience would vary.

The SBP programming was offered exclusively online. This was an adaptation of the original project plan caused by institutional responses to COVID-19. Thus, the outcomes are also notable as demonstrating efficacy of online SBP programming for providing meaningful educational experiences. The value assigned to various elements of the programming by participants and the variety of topics mentioned support this conclusion as do the increases in awareness of engineering opportunities and general in interest in engineering and a career in engineering.

The next step at the sponsoring institution will be tracking enrollment and persistence of bridge program participants to substantiate efficacy as a recruiting and preparation tool. The final analysis desired will be a comparison of the investment per student versus the income per student as represented by persistence and revenue generation. However, current indications are that institutionalizing the summer bridge program may prove to be beneficial to prospective participants, to participants who become students at the university (current retention of 2020 participants is higher than institutional averages), and for the institution as a recruiting and student preparation tool.

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Appendix

Table A

Comparison of Pre- and Post-Participation Survey Responses for the Summer Bridge Program

Query	Period	Mean	SD	Mode	Sign.
I have been taught a design process specific to engineering.	Pre-2020	4.77	2.96	3	< .001
	Post-2020	8.19	1.74	8	
	Pre-2021	5.0	2.85	5	< .001
	Post-2021	8.45	2.16	10	
I have used an engineering design process to complete a project.	Pre-2020	4.65	3.41	4	< .001
	Post-2020	8.61	1.69	10	
	Pre-2021	5.84	3.09	10	< .001
	Post-2021	8.77	2.02	10	
I can describe the relationship of licensure for engineers and public safety in the use of products designed by engineers.	Pre-2020	2.36	2.44	1	< .001
	Post-2020	8.08	1.66	8	
	Pre-2021	5.21	2.73	5	< .001
	Post-2021	8.63	2.03	10	
I can explain how calculus is important in creating technological solutions to human problems or needs.	Pre-2020	4.56	2.86	6	< .001
	Post-2020	8.08	1.70	10	
I can explain how engineering is different than science and mathematics.	Pre-2020	5.48	2.80	7	< .001
	Post-2020	8.53	1.84	10	
	Pre-2021	7.21	3.09	10	< .001
	Post-2021	8.49	1.86	10	

Table 2

Comparison of Pre- and Post-Participation Survey Responses for the Summer Bridge Program

Query	Period	Mean	SD	Mode	Sign.
I know several types of jobs or projects in which engineers in each of the major disciplines might be involved.	Pre-2020	6.13	2.84	7	< .001
	Post-2020	9.08	1.40	10	
	Pre-2021	6.89	2.45	8	< .001
	Post-2021	8.79	1.79	10	
I can explain how simultaneous equations apply in engineering.	Pre-2020	4.0	3.0	0	< .001
	Post-2020	7.47	2.80	10	
	Pre-2021	5.30	2.55	5	< .001
	Post-2021	8.26	2.19	10	
I can explain how the types of material that could be used in a structure impact the way the structure can be designed and built.	Pre-2020	4.90	2.93	7	< .001
	Post-2020	8.31	1.79	10	
	Pre-2021	5.69	2.84	5	< .001
	Post-2021	8.30	2.07	10	
I can correctly use the phrases statically determinate and statically indeterminate when describing engineering analysis.	Pre-2020	3.57	2.95	0	< .001
	Post-2020	7.14	3.03	10	
	Pre-2021	4.61	2.76	6	< .001
	Post-2021	8.0	2.14	10	
I can define computer science.	Pre-2020	4.74	3.02	5	< .001
	Post-2020	8.28	1.77	10	
	Pre-2021	6.11	3.01	10	< .001
	Post-2021	8.49	1.64	10	
I can describe what people who work in computer science do.	Pre-2020	4.31	2.93	4	< .001
	Post-2020	8.44	1.59	10	
	Pre-2021	5.57	3.10	8	< .001

	Post-2021	8.53	1.61	10	
I can give accurate examples of the types of projects and problems on which computer scientists work.	Pre-2020	3.87	2.45	5	< .001
	Post-2020	8.08	1.83	10	
	Pre-2021	4.89	2.85	8	< .001
	Post-2021	8.49	1.64	10	
I can describe the use of algorithms in computer science.	Pre-2020	3.38	2.78	0	< .001
	Post-2020	7.47	2.12	10	
	Pre-2021	4.59	3.00	3	< .001
	Post-2021	7.98	2.18	10	
I could explain to a friend what it means to solve a computer science problem at the conceptual level.	Pre-2020	3.21	2.83	0	< .001
	Post-2020	7.36	2.07	7	
	Pre-2021	4.78	2.97	5	< .001
	Post-2021	8.04	2.17	10	
I can write a formula in Excel.	Pre-2020	6.94	2.86	10	< .001
	Post-2020	9.14	1.33	10	
	Pre-2021	7.59	2.57	10	< .001
	Post-2021	8.96	1.70	10	
I know several options for visualizing data in Excel.	Pre-2020	5.58	3.26	8	< .001
	Post-2020	8.63	1.68	10	
	Pre-2021	6.65	2.65	10	< .001
	Post-2021	8.61	1.92	10	
I know how to nest formulas in Excel.	Pre-2020	4.13	3.36	0	< .001
	Post-2020	7.86	2.33	10	
	Pre-2021	4.41	3.19	1	< .001
	Post-2021	8.0	2.36	10	
I have seen how 3D modeling software can be used in engineering design and analysis.	Pre-2020	5.73	3.51	8	< .001
	Post-2020	8.64	2.04	10	

Table 2

Comparison of Pre- and Post-Participation Survey Responses for the Summer Bridge Program

Query	Period	Mean	SD	Mode	Sign.
	Pre-2021	6.55	3.30	10	< .001
	Post-2021	8.74	1.92	10	
I can explain how 3D modeling software serves as a communication tool for designers, manufacturers, and end users.	Pre-2020	6.10	3.22	10	= .001
	Post-2020	8.31	2.17	10	
	Pre-2021	5.98	3.08	5	< .001
	Post-2021	8.80	1.67	10	
I know the data science life cycle.	Pre-2020	2.19	3.10	0	< .001
	Post-2020	7.06	2.47	10	
	Pre-2021	3.36	2.92	0	< .001
	Post-2021	8.04	2.24	10	
I can describe how geographic information systems relate to spatial data, attribute tables, and temporal data.	Pre-2020	3.63	3.45	0	< .001
	Post-2020	6.94	2.51	7	
I can define mathematical modeling.	Pre-2021	4.57	2.70	5	< .001
	Post-2021	8.22	1.70	10	
I can give examples of how mathematical modeling has been used to address engineering tasks/challenges.	Pre-2021	4.95	2.68	5	< .001
	Post-2021	8.27	1.90	10	
I can explain one or more ways of visualizing temporal and spatial data.	Pre-2021	4.38	2.85	5	< .001
	Post-2021	8.22	2.08	10	
I can explain how an understanding of chemistry is applicable in engineering.	Pre-2021	5.98	2.67	7	< .001
	Post-2021	8.47	1.87	10	
I can describe some ethical challenges that arise in engineering.	Pre-2021	6.65	2.52	5	< .001
	Post-2021	8.70	1.88	10	
I have experience working with a group of peers on an engineering project.	Pre-2021	7.39	2.45	10	< .001
	Post-2021	9.02	1.80	10	