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Work in Progress: Design Activities in a Summer Engineering Program Implemented in Both Virtual and Hybrid Modality

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Work-in-Progress: Design Activities in a Summer Engineering Program Implemented in Both Virtual and Hybrid Modality

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 third year of the SBP, which was held in hybrid mode (virtually and on-site or face-to-face) in summer 2022. The objective of this SBP is to increase academic motivation of the student participants, and increase retention using high impact design 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 third annual SBP in the NSF IUSE grant implemented at TAMUK, and to inform and solicit feedback from other undergraduate engineering education experts. Since this edition of the SBP was conducted in a hybrid mode, while the preceding two were conducted in a virtual-only mode, the assessment of program efficacy with respect to the modality difference is important to share with the wider engineering community.

Texas A&M University-Kingsville is located in south Texas, an area where Hispanic populations are the majority [4]. TAMUK is a Hispanic-serving institution (HSI) and has a student population that is majority Hispanic, 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]. A second impetus to implement this SBP at TAMUK was to address challenges documented in the literature, such as poor sense of belonging, lack of cultural support, academic deficiencies, and lack of faculty support, which exist specifically for Hispanic students at TAMUK [12].

The third impetus of the SBP was to help participants to identify as engineering students, which has been shown to impact student retention positively [13-15]. The SBP program was implemented to address Hispanic student challenges, thereby targeting for advancement the identity as a student engineer and building upon the existing research for summer programs in STEM fields. A total of 46 students were enrolled in the 2022 SBP, with 22 of them attending virtually and 24 attending on-site.

Program Implementation

The 2022 SBP program consisted of 2 to 4-hour afternoon sessions held each weekday in hybrid mode (virtual and on-site participants together) each weekday for a period of three weeks in July. Both the first and second offerings of the SBP were held virtually in summer 2020 and 2021 due to COVID-19 conditions prevalent at the time, while this offering of the SBP was held as a hybrid (both virtual and on-site participation of students) as the COVID conditions eased. A Zoom platform was used to conduct the virtual port of the third SBP. A weekly stipend was provided to each participant as an incentive for continued attendance, and this stipend was paid after the fact for each week of the program. The content of the SBP program included a mix of engineering presentations on engineering-related topics by TAMUK faculty in engineering or closely related STEM fields, guest presentations or panel discussions by working engineers, and high impact engineering design projects. Participants were assigned to discipline-specific teams so that these projects aligned with students' interests or declared engineering major. A total of 13 teams were formed amongst the 46 SBP participates, and these teams fell into the following discipline-related cohorts: Chemical and Environmental Engineering (3 teams), Civil and Architectural Engineering (2 teams), Electrical Engineering and Computer Science (3 teams), Mechanical and Industrial Engineering (3 teams), and Industrial Technology (2 teams). For the on-site participants of the SBP, additional activities were held each morning, and these activities centered around either student success or engineering lab tours. The student success topics presented to the on-site students included time management, GPA calculation, resume building and internship opportunities, library services, and personal learning styles.

The faculty lectures discussed the engineering design process; engineering disciplines; importance of mathematics in engineering, chemistry and computers in engineering; lean manufacturing; engineering mechanics; data analysis and visualization; 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 five stand-alone presentations, including two guest speakers associated with NASA and the Texas General Land Office. The three panel discussions invited guests from different career stages as follows: (a) a recent winning senior design team from in TAMUK COE, (b) early career professionals, and (c) seasoned engineers. Each panel had five to six speakers. With stand-alone presentations and panel discussions, a total of 19 industry professionals participated in the SBP, thirteen of whom were Hispanic and seven of whom were female, two categories of individuals who are underrepresented in engineering [16, 17]. Guest speaker diversity was a program priority, since a high percentage of participants were female (38%) and Hispanic (62%), This helped the SBP participants 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 the team-based engineering project that students performed during the majority of the program. Experiential learning activities were selected by the faculty to introduce participants to engineering problem-solving. In addition, the 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 per specific cohorts associated with disciplines, as previously described.

The short, 1-day engineering challenges were completed on the first 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. These engineering challenges were hands-on activities conducted in a group format. For those students that participated in the SBP virtually, kits containing necessary materials were mailed to each student the week before the program began.

Table 1. 1-Day Engineering Challenge Activities

Cohort	**Challenge**	**Objective**
Civil and Architectural	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 I	Toxic Popcorn	Students tasked with removing 'toxic' container without touching it directly.
Chemical II	Fabric Waterproofing	Students challenged with testing various oleophilic materials for their ability to make a cotton fabric swatch waterproof or water resistant.
Chemical III	Paper Recycling	Students tasked with devising a procedure for screening a paper pulp to result in recycled paper with either strength or writability characteristics.
Electrical and Computer Science	Cartographer's Dilemma	Students color a segmented map without allowing common borders to have the same color.
Mechanical I	Marshmallow	Students challenged to construct a tall structure using marshmallows and spaghetti.
Mechanical II	Tall Tower	Students challenged to construct a tall structure to hold a golf ball using only straws, paper clips, and pipe cleaners.
Mechanical III	Cardboard Robot Hand	Students tasked with constructing a cardboard extension of their hand with moving fingers actuated by string attachments to their human fingers.

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) solar-powered pump system, liquid-liquid extraction, and municipal water supply alternatives, for three Chemical and Environmental Engineering groups, (b) design of a truss bridge for two Civil and Architectural Engineering groups, (c) building and programming a line-following robot for two Electrical Engineering and Computer Science groups, (d) plastic part design and 3-D printing for three Mechanical and Industrial Engineering (e) use of recyclable plastics for wind-turbine blades and (f) finally one group for an engineering optimization coding study. 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- and second year offerings (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 prior publications [20, 21]. The projects described there are those listed as items b, and d above.

The Chemical and Environmental Engineering cohort included three student teams, two of which were attending the SBP on-site and one that was attending virtually. These three groups each had a different project, which was beneficial for these students in that they were able to see their peers working on different tasks in their same discipline area. The first on-site team investigated the potential use of a renewable energy source such as solar photovoltaics (PV) to power a water pump needed to fill above ground water system tanks in the event of an extended power outage, such as from a hurricane or winter freeze event. The students investigated the pump output as a function of discharge height, as well as the energy output associated with a PV array, and how that energy was best stored and utilized for the pump. The second on-site team was tasked with investigating different means to utilize liquid-liquid systems, such as an immiscible oil and water, to transfer a chemical that was soluble in both of the phases. Liquid-liquid extraction is an important chemical process for separation and purification of chemicals. The students investigated solute concentrations in the aqueous phase using refractive index, as a function of different mixing techniques. The virtual project team prepared a paper study on the energy requirements and costs for developing alternative potable water supplies for medium size cities in our region of the state. Since the region is in a semi-arid area and the local river resources are completely allocated, possibilities for new water sources include pipelines to collect and deliver water from other river basins or seawater desalination. An overarching objective of each of these projects was to provide the students with some experience in mass balance applications, fluid flow and energy processes.

The cohort for mechanical and industrial engineering includes two student teams who worked on a 3D printing project. Students were given instructions on how to design using a 3D modeling software (SolidWorks), rapid prototyping using a FDM technology 3D printer, and basic simulation on SolidWorks. Once the students gained some basic knowledge on 3D modeling, student groups were asked to select a mechanical mechanism and reproduce the same using the 3D printing rapid prototyping technology. The mechanism selected should be an assembly with multiple parts. Students started by designing the parts, which were later 3D printed and assembled. The student groups were also given an opportunity to make improvements to the existing design for better functionality. Finally, the groups delivered the project using a presentation and report. Students gained some fundamental understanding of 3D modeling, Simulation and 3D printing while working on this project. Students were successful in completing the project and appreciated the learning opportunity.

The mechanical, industrial management, and applied engineering students were assigned to research possible recyclable materials and sustainable manufacturing methodologies that can be used in wind turbine blade production. Wind energy is a promising renewable energy source that is gaining attention due to its low carbon footprint and minimal environmental impact compared to other energy sources. World Energy Council (WEC) predicts that by 2050, wind power will be the primary source of electricity from renewable energy systems. While the world is moving toward wind as a replacement energy source, there are still blind spots to be carefully considered. Researchers estimate that over the next twenty years, the United States will have to dispose of more than 720,000 tons of material from wind turbines. Therefore, students were assigned to investigate recyclable materials which can be used in wind turbine production and produce a working prototype of the wind turbine with the suggested material for this research. Students selected to utilize additive manufacturing technology and thermoplastic materials such as PLA, PVC, and ABS to prototype a working model of a wind turbine made out of fully recyclable materials. Students could demonstrate the prototype model and produce enough electricity to light a bulb. The intention of this research was to develop a thorough understanding of sustainable energy and green production.

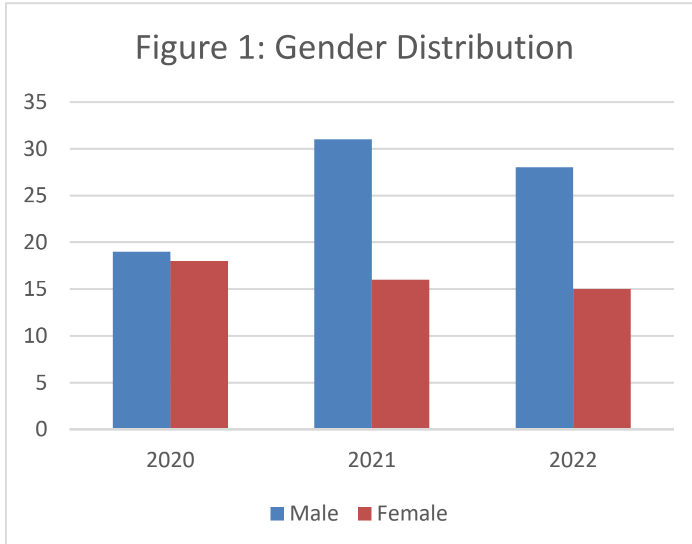
A cohort of electrical and computer science students worked on an engineering optimization problem seeking the shortest path from a starting point to an ending point. In this project, given any location of a monkey and a banana on a 50x50 grid, under some constrictions for how the monkey could move, 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 of how 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.

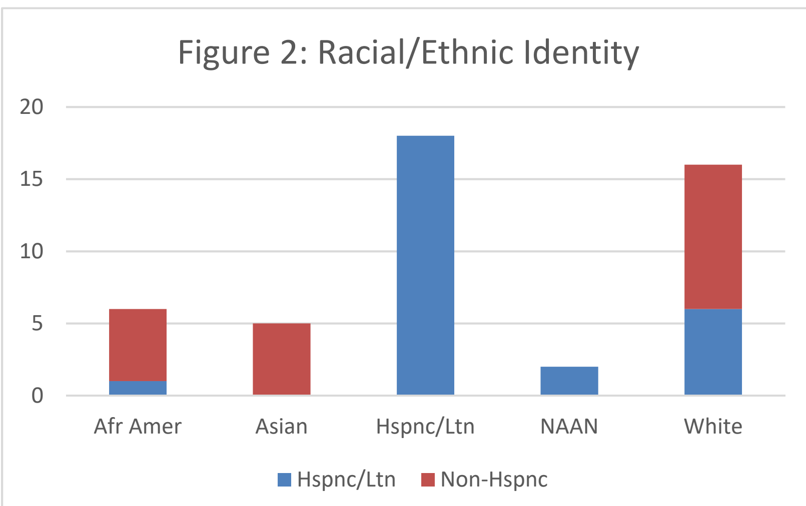
The in-person Electrical Engineering and Computer Science student cohort consisted of two teams that conducted a project involving building and programming a line following robot. The student teams were first tasked with assembling and connecting the necessary components for the robot, adding pieces incrementally to the robot chassis. Once assembly was completed, the teams utilized a credit card sized computer (Raspberry Pi) to write and debug a Python program capable of gathering and processing input from infrared sensors to provide guidance and enable the robot to follow a track. Once the program was complete, the computer board was then deployed to run the guidance program and keep the robot on track. Teams then tested their robots on a track and adjusted their hardware and software as necessary to optimize their robot's performance.

Results

All project participants were asked to complete a pre- and post-participation survey in each year of programming. Outcomes from 2020 and 2021 have been discussed in prior publications [20, 22]. 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 learning objective statements submitted by the participating faculty. Adjustments to programming were made for 2021 based on the faculty and students' experiences in the pilot program and for 2022 due to additions to the programming. This involved addition of material about chemistry and ethics in engineering in 2021. The additions in 2022 covered lean manufacturing, a new topic in the summer offering, and the presentations for on-site participants regarding time management, GPA calculation, resume building and internship opportunities, library services, and personal learning styles. This paper describes the 2022 programming specific to engineering but outcomes from 2020 and 2021 assessment are included to support conclusions drawn. Survey questions asked and analysis of data related to the student support services and library presentations, while not discussed herein, are available from the authors upon request.

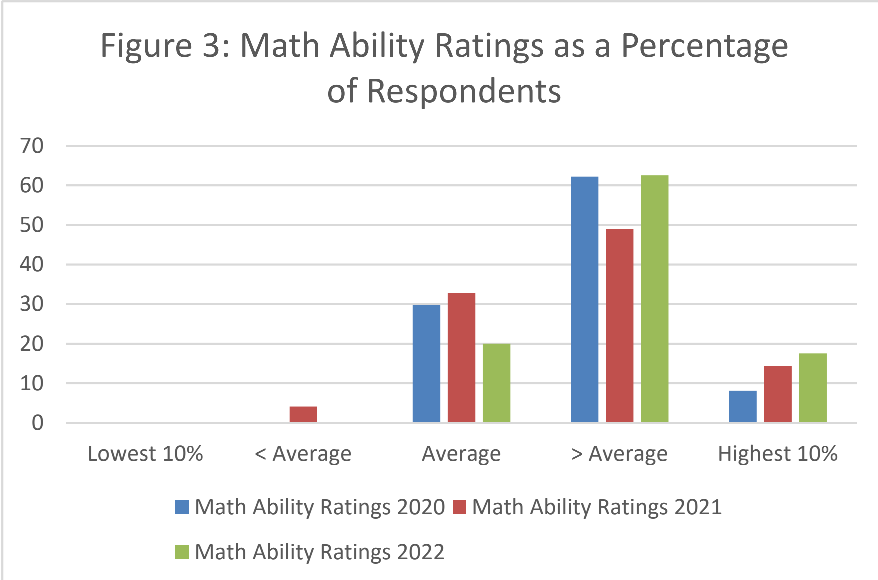
Figure 1 is a graph of the count of females and males that participated in the three years of programming. The count of females participating stayed relatively constant with 18 females in 2020, 16 in 2021 and 15 in 2022. Yet, the total participant count was higher in 2021 and 2022, 49 and 43 students respectively while the 2020 count was 37. The net gain in participants occurred among males who were 51.4% of the 2020 cohort, 63.3% in 2021, and 65.1% in 2022.





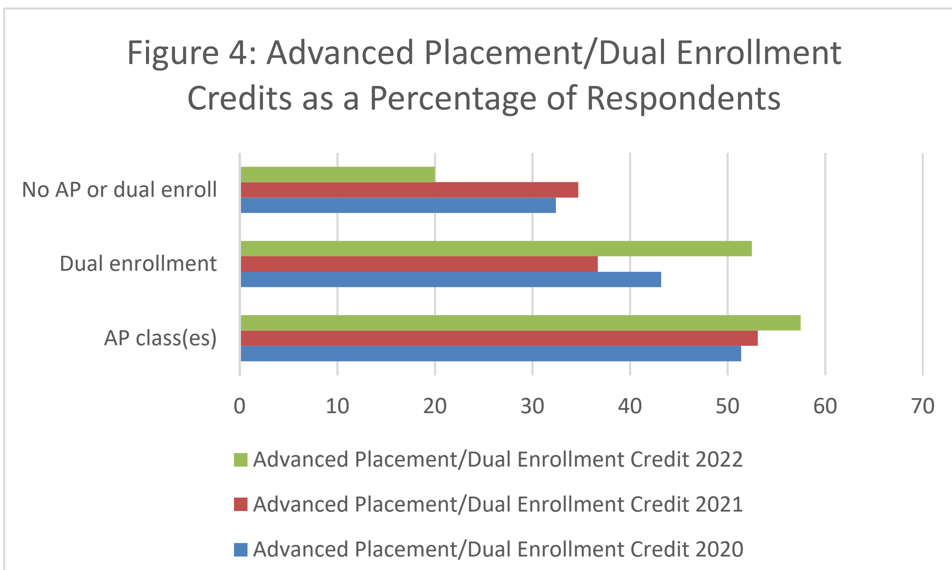
The racial/ethnic identity of the 2022 cohort is graphed in Figure 2. Each column is a racial category selected by at least one participant. The color coding represents parties who noted they identified ethnically as Hispanic/Latinx (blue) or who identified as non-Hispanic (red). The total count of the racial identities exceeds the participant total as students were allowed to select all descriptions that applied to their racial identity with parties selecting up to three categories. Hispanic/Latinx individuals saw themselves almost exclusively as Hispanic/Latino, Native American/Alaska Native, or White (one selection of Black/African American). Non-Hispanics were African American, Asian, and White. This distribution of racial/ethnic identities was similar to those in the two preceding cohorts [20, 22].

Many of these students were also first-generation college students (defined in the question as "neither of my parents/guardians possesses a college degree") [20]. The 2022 cohort had fewer first-generation students than preceding years, 47.5% versus 62.2% in 2020 and 55.1% in 2021. There were also three respondents in 2022 who did not know whether they were first-generation college students.



In all three years of programming, the majority of participants felt their math skills were "above average" or higher in comparison to their classmates, 70.3% in 2020, 63.3% in 2021 and 80.0% in 2022. The remainder classified themselves as "average" with the exception of two students in 2021 who felt they were below average. Thus like in preceding years, "most of the students should have been well positioned for the mathematical content in the SBP" [22].

"The volume of Advanced Placement and dual enrollment experience in the cohorts provided further support of academic preparation" [22] (Figure 4). "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" [22]. "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" [22] while 2022 counts were 24 for AP, 221 for dual enrollment, 12 with both, and 8 with neither.



The demographics outlined for the three cohorts indicate several differences existed year-to-year. These were the gender distribution, the percentage of first-generation college students, and percent with dual enrollment credit and those not having participated in Advanced Placement or dual enrollment courses. This variation, as well as the different forms of program presentation (online and hybrid), make the data set valuable. Three groups that departed from each other in several important ways have been instructed using the same curriculum but that curriculum was presented in two different ways. As a result, any statistically significant patterns reoccurring would represent a strong case that the cause was the curriculum.

There were strong but not 100% participation rates on the surveys in 2020 and 2021. Thirty-six of 37 2020 summer program participants accessed the pre-participation survey while 49 of 50 participants did in 2021. “All 37 participants completed the post-participation survey in 2020” [22]. “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” [22]. All members of the 2022 cohort accessed the pre-participation survey, 46 submissions (three dropped out during the summer for personal reasons), while two did not respond to the post-participation survey. Participation at such high levels guarantees that the response group was representative of the cohort and that the outcomes can be treated as an accurate reflection of the participants’ opinions. Confidence intervals for the surveys were all lower than 3.5% at a 95% level of confidence.

In each year, the pre-participation response sets facilitate “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” [22] with as many as 27 different topics. “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” [22]. “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” [22]. The 2021 and 2022 cohorts reported higher levels of experience than the 2020 cohort. The means for the prompts were grouped closer together and higher up the scale than in 2020 (one mean above 6.0 in 2020 while eight were in 2021 and six were in 2022). Interestingly, the sorts of topics by mean did not result in similar rankings for each year. Collectively, these factors point to cohorts having different backgrounds. Any positive outcomes that occurred consistently given this and the other variation in the cohorts, would, as a result, point to the instructional experiences as the influencing factor.

“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” [22]. The 2022 data was analyzed with paired-sample *t* tests. The 2022 data is represented in the graphs below with outcomes from applying descriptive and inferential statistics included in a table in the Appendix. That table includes the outcomes for all three years so that comparisons can be made and broad conclusions stated in this presentation.

Figures 5, 6, and 7 are graphs of the pre- and post-participation mean ratings for each of the topics in general engineering skill, computer science and Excel skill, and lean manufacturing plus modeling and visualization queries. The graphs clearly illustrate large gains in means pre- to post-participation in every topic area. The table in the Appendix includes results of analyses

Figure 5: 2022 Mean Ratings for General Engineering Queries

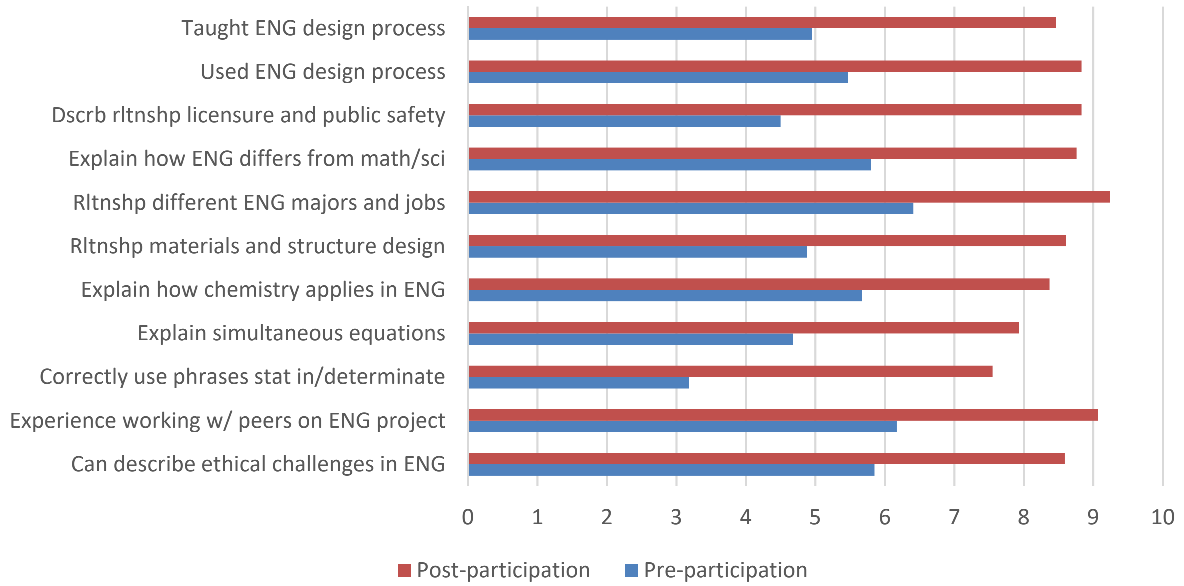
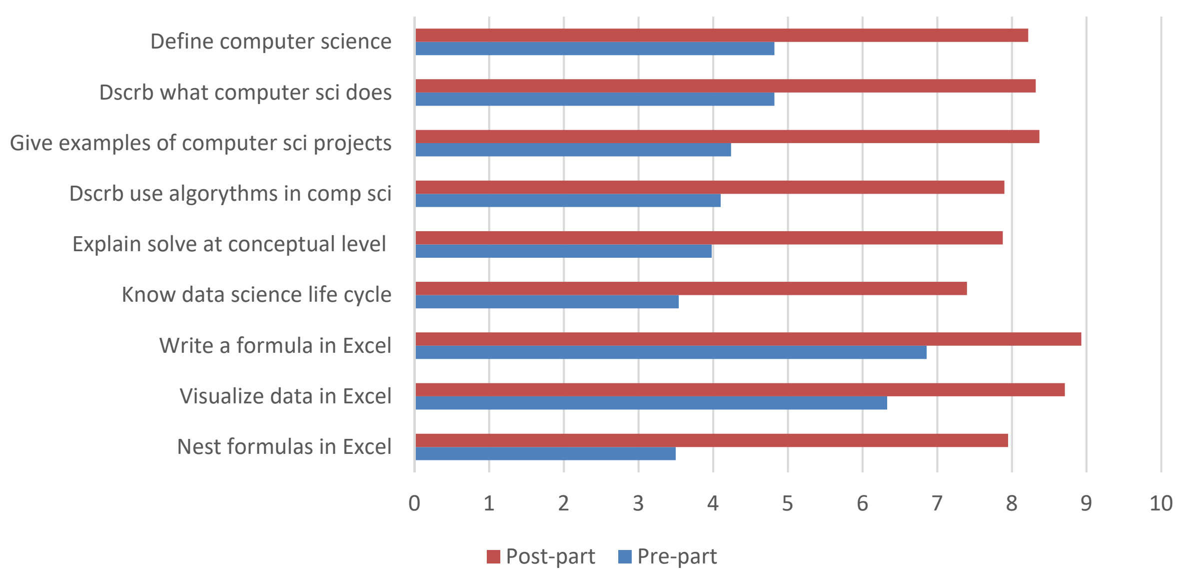
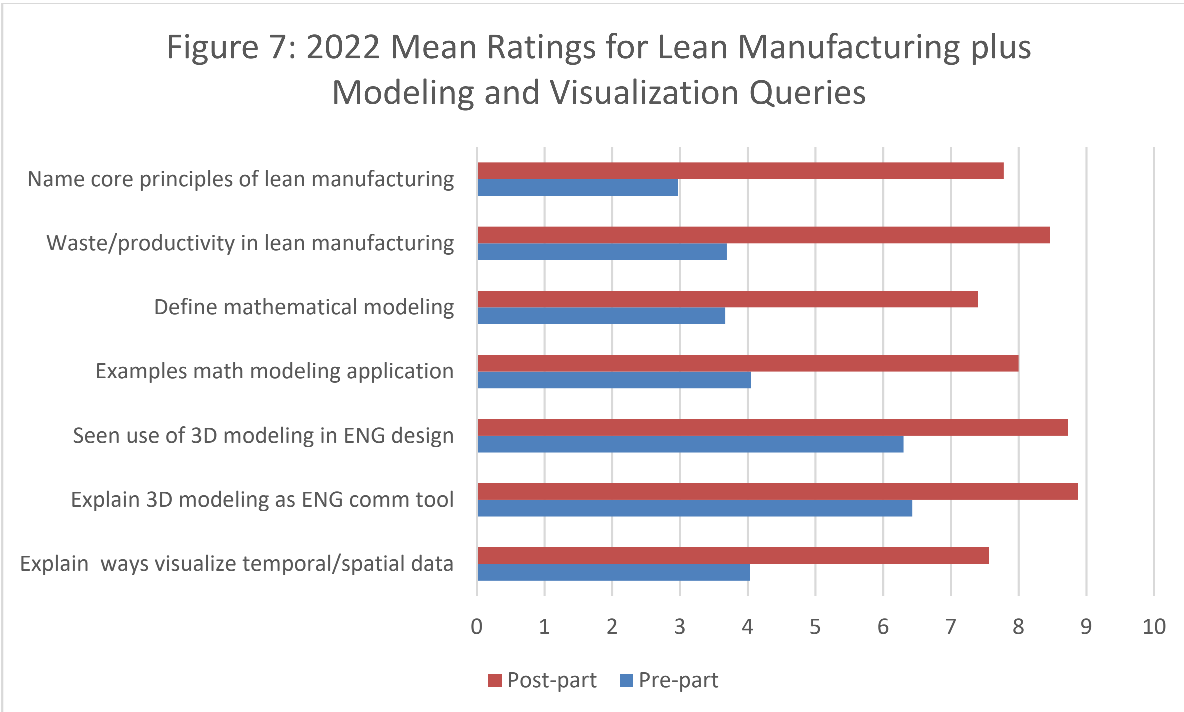


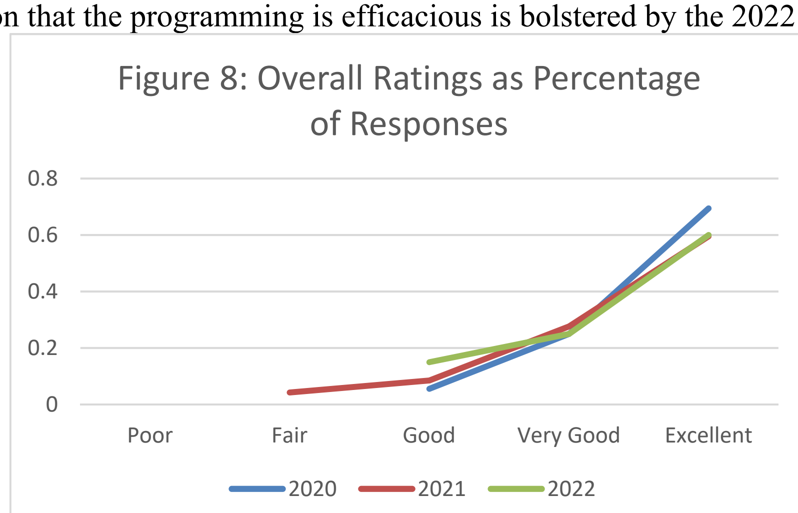
Figure 6: 2022 Mean Ratings for Computer Science and Excel Skills Queries





of the statistical significance of these differences. Every one of the differences was significant at the < .001 level. All of the pre- to post-participation differences in 2020 and 2021 for this group of questions were also highly significant [20, 22] (values listed in the Appendix). Given the consistent findings across three years with online and hybrid delivery and groups that showed variation in background and experience, the clear indication is "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" [22].

As was stated in [22], "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." This assertion that the programming is efficacious is bolstered by the 2022 data which adds another year of statistically significant increases in understanding and skill in the general engineering, computer science and Excel skills, modeling and visualization topic areas with similar results for a new topic, lean manufacturing. "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?’” [22] The question employed a five-point Likert scale (Poor to Excellent) and responses are plotted in Figure 8. Of the 123 responses received, only two were Fair with 88.6% occurring as Very Good or Excellent.

Results: awareness of and interest in engineering, career goals

“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.’” [22].

Submissions occurred as ratings between zero (0) and ten (10) with zero indicating “no impact” and ten “a very large change.” “One student did not respond to this set of three questions in 2020” [22], two did not in 2021, but all informants responded in 2022.

Figure 9 is a box and whiskers plot of responses from all years. The three topic areas are marked by grey banners labeled awareness, interest and career goals, and there is three years of data displayed for each topic. The colored boxes, blue for 2020, red for 2021 and orange for 2022, represent the response data by year. The boxes illustrate the range of ratings in which 50% of the submissions occurred for each year which in all but one case was between the values of eight and ten on a ten-point scale. There is one line, “whisker,” below each box rather than one above and below. This occurred because in each case the ratings were generally high with 50%

Figure 9: Ratings for Awareness of and Interest in Engineering plus Refining Career Goals Queries

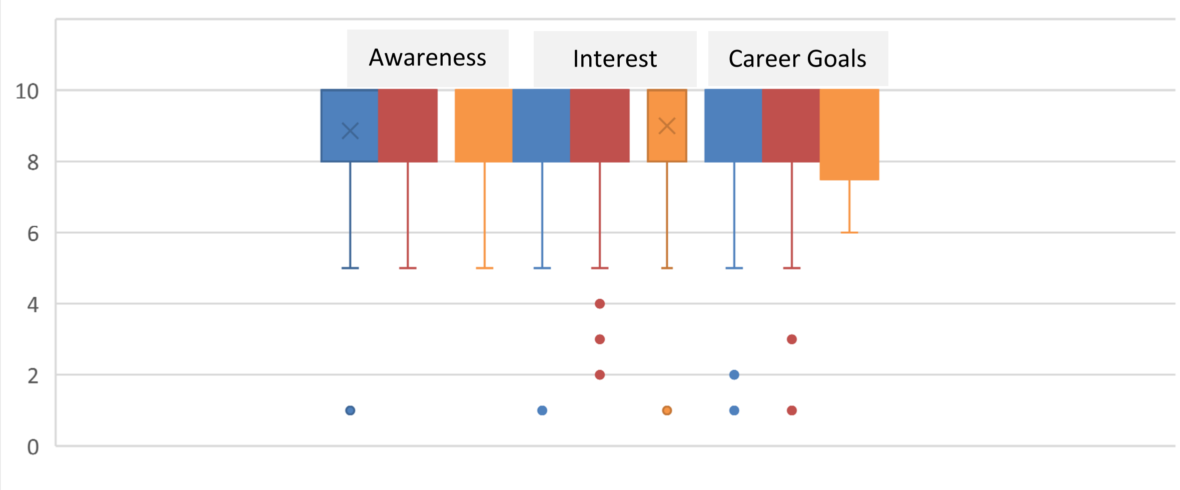


Figure 9 Legend: blue = 2020, red = 2021, orange = 2022

occurring between 8 and 10 in eight of nine cases and between 7.5 and 10 in the ninth instance. Thus, the upper edge of the boxes occurs at the highest point on the scale eliminating need for an upper "whisker" as there was no upper taper of ratings. The line and any dots below the boxes indicate the remaining range of ratings with the dots denoting individual outlier submissions. The outlier submissions "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" [22]. Substantial prior experience can exist for one party across multiple topics. "In fact, all the ratings of one were submitted by the same party in 2020" [22].

As has stated above, the mean rating for each topic, abbreviated as awareness, interest and career goals in Figure 9, was high in the annual data sets. The mean ratings were: (1) 8.86 in 2020, 8.83 in 2021 and 8.95 in 2022 for increasing awareness of the variety of opportunities for people who study engineering, (2) 8.72, 8.60 and 9.0 respectively for increasing interest in studying engineering, and (3) 8.50, 8.38 and 8.90 for helping to refine career goals. These are patterns Figure 9 clearly illustrates as there was a narrow range of ratings that skewed high, 50% occurring in the top quintan of the rating scale, with a very limited number of low, outlier submissions (e.g., only one value outside the range of 5 to 10 in all three years for awareness of the variety of opportunities available to people who study engineering).

"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" [22]. Open coding [21] of the submissions for all three years for the first question resulted in ten primary themes for the most valuable form of learning [22].

- 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.

Comments submitted by participants in 2022 occurred in each of the above categories, with the exception of understanding opportunities for females, and addressed some specifics that had not been part of prior programming like the presentations made by Career Services and university library personnel and the morning lab sessions for students attending on campus.

"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,…'Every activity and class as a whole…[and] all classes left me great experiences' from a 2021 participant" [22] and "Everything was very helpful" from a 2022 informant. In 2022 and the preceding years, "the most common specific response was that the group activity had been most valuable" [22]. Yet, "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, 22].

"The final question was: 'Is there anything else you would like the project team and faculty members to know about your experience this summer'" [22]? "The responses were primarily expressions of praise and thankfulness" [22]. Students in 2022 and both preceding years "noted that gaining familiarity with personnel at the university made them more likely to consider it as their next stop in higher education" [22].

Conclusions and Future Direction

As stated in [22], "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 on three different cohorts in three years "substantiates the educational efficacy of the process" [22] especially given the differences that existed. The instructional modality was online for the first two years with hybrid, online and on campus instruction added in the third. While all groups had backgrounds that prepared them for the mathematical content of the program, there was variation in gender ratios, percentage of participants who were first-generation college students (low of 47.5%, high of 62.2%), levels of ability to participate in and experience with Advanced Placement and dual enrollment courses, and prior experience in up to 27 program-related engineering topic areas.

That uniformly strong and positive outcomes were achieved with three cohorts comprised mostly of individuals identifying with underrepresented groups (~70%) many of whom where first-generation college students (43.1%) is also noteworthy as is the relatively high percentage of female participants (39.8%). "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" [22]. Analysis of survey responses by team project type was not completed as dividing the parties by year and then project type resulted in multiple groups with total informant counts too small to support statistical analysis. The only caveat necessary when considering the outcomes 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" [22].

"The SBP programming was offered exclusively online" [22] the first two years with the cohort split between online and on campus participants in the summer of 2022. As was noted in [20, 22], the online programming "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” [22] and the overall ratings of the summer experience.

“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” [22]. These processes can be completed for a reasonable number of students beginning in the fall of 2023 when participants from 2020 will have had three years to transition to or continue at the university and persist in study and those from 2021 will have had two years.

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Appendix

Table A

Comparison of Pre- and Post-Participation Survey Responses Regarding Engineering Concepts

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	
	Pre-2022	4.95	2.65	5	< .001
	Post-2022	8.46	1.62	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	
	Pre-2022	5.47	3.06	7	< .001
	Post-2022	8.83	1.89	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	
	Pre-2022	4.50	2.82	7	< .001
	Post-2022	8.83	1.71	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	= .004
	Post-2021	8.49	1.86	10	
	Pre-2022	5.80	1.96	5	< .001
	Post-2022	8.76	1.39	10	
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	
	Pre-2022	6.41	2.64	7	< .001
	Post-2022	9.24	1.23	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	
	Pre-2022	4.68	2.38	4	< .001
	Post-2022	7.93	1.94	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	
	Pre-2022	4.88	2.66	7	< .001

Table A

Comparison of Pre- and Post-Participation Survey Responses Regarding Engineering Concepts

Query	Period	Mean	SD	Mode	Sign.
	Post-2022	8.61	1.69	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	
	Pre-2022	3.18	2.67	1	< .001
	Post-2022	7.55	2.01	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	
	Pre-2022	4.82	2.74	3	< .001
	Post-2022	8.22	2.21	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	
	Pre-2022	4.82	2.75	3	< .001
	Post-2022	8.32	1.98	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	
	Pre-2022	4.24	2.54	3	< .001
	Post-2022	8.37	1.78	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	
	Pre-2022	4.10	2.99	3	< .001
	Post-2022	7.90	2.32	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	
	Pre-2022	3.98	2.98	1	< .001
	Post-2022	7.88	2.22	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	= .003
	Post-2021	8.96	1.70	10	
	Pre-2022	6.86	2.90	10	< .001
	Post-2022	8.93	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	
	Pre-2022	6.33	2.88	10	< .001
	Post-2022	8.71	2.20	10	

Table A

Comparison of Pre- and Post-Participation Survey Responses Regarding Engineering Concepts

Query	Period	Mean	SD	Mode	Sign.
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	
	Pre-2022	3.50	2.84	1	< .001
	Post-2022	7.95	2.66	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	
	Pre-2021	6.55	3.30	10	= .002
	Post-2021	8.74	1.92	10	
	Pre-2022	6.30	2.95	8	< .001
	Post-2022	8.73	2.07	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	
	Pre-2022	6.43	2.99	9	< .001
	Post-2022	8.88	1.45	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	
	Pre-2022	3.54	2.53	4	< .001
	Post-2022	7.40	2.36	8	
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	
	Pre-2022	3.67	2.48	5	< .001
	Post-2022	7.40	2.06	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	
	Pre-2022	4.05	2.57	3	< .001
	Post-2022	8.00	1.93	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	
	Pre-2022	4.03	2.69	4	< .001
	Post-2022	7.56	2.63	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	
	Pre-2022	5.67	2.33	6	< .001
	Post-2022	8.37	1.75	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	
	Pre-2022	5.85	2.39	8	< .001
	Post-2022	8.59	1.86	10	
I have experience working with a group of peers on an engineering project.	Pre-2021	7.39	2.45	10	= .006
	Post-2021	9.02	1.80	10	
	Pre-2022	6.17	3.44	10	< .001

Table A

Comparison of Pre- and Post-Participation Survey Responses Regarding Engineering Concepts

Query	Period	Mean	SD	Mode	Sign.
	Post-2022	9.07	1.44	10	
I can the concepts waste and productivity as they apply in lean manufacturing.	Pre-2022	3.69	2.95	1	< .001
	Post-2022	8.46	1.84	10	
I can name at least three of the five core principles in lean manufacturing.	Pre-2022	2.97	3.17	1	< .001
	Post-2022	7.78	2.43	10	