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Pre-college design ”Tech for Good”: As a member of a collaborative team, students believe they can change the world.

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Pre-college design
"Tech for Good": As a member of a collaborative team, students believe they can change the world (Evaluation)

Abstract

This paper describes the project facilitation strategies and evaluation results from a 3-week engineering design program for high school students. The program features student-led project ideation and teaming to develop "Tech for Good". Students were tasked with designing, building, and evaluating a solution to a problem that they feel is important to society and that has the potential to improve the lives of others. Students reviewed UN Sustainable Development Goals, explored global grand challenges, and iterated on generative AI prompts to support their brainstorming. In this paper, we will share our program curriculum with a step-by-step guide for student-led project ideation and team selection.

The mixed methods evaluative approach (n=12) investigated the students' perceived gains in technical skills, careers awareness, engineering identities, and attitudes towards engineering. Pre/post-measures quantitative findings highlight increases in hands-on skills, understanding of the design process, and awareness of science/engineering careers. Post-program interviews illuminate student understanding of teamwork, technical communications, and project management. Many students were surprised by the importance of collaborative teams both in their own projects and in the professional examples they learned about from visiting scientists and engineers. Team projects included designs for prosthetics, bike safety, adaptive devices, medical care, and crop irrigation.

Most students believed they gained the ability to improve the world through their designs, emphasizing that they can accomplish much more when working on a team. Additional interview findings focused on students' experience with career sessions where they engaged with science/engineering professionals including local entrepreneurs. Students expressed confidence in understanding the wide array of engineering-related careers and steps needed to pursue these fields. The summer program reinforced student interest in STEM majors and careers with enthusiasm for "design for good."

1. Introduction

This paper details the project facilitation strategies and evaluation results from a 3-week engineering design program for rising high school juniors and seniors. The program engages students in an active application of design and engineering problem-solving while providing them the agency to identify problems of societal importance that are of interest to them. Grappling with ill-defined problems within a structured framework and in a supportive environment gives students confidence to take on real-world problems [1], [2]. We guided them through a systematic engineering design process with concurrent technical skill and professional skill development. The program emphasized collaboration and communication through bi-weekly technical reports, practice and final presentation, website portfolios consistent with many pre-college design programs like Silvestri et al.'s work [3] and incorporating elements of empathy and ethics as recommended by Povinelli [4].

This program, first offered in 2022 at Duke University, was an outcome of a standing departmental committee focused on the dissemination and broader impact of mechanical engineering and materials science. One goal was to establish outreach programs that would provide meaningful, active learning for the student, in a collaborative and cooperative community indicative of an engineering design company. We anticipated that these immersive experiences would increase interest, awareness, and retention in engineering education and careers.

2. Pedagogical approach

The pedagogical approach for the program is rooted in educational theory based on the Experiential Learning Theory (ELT) described by Kolb [5] and Situated Learning Theory (SLT), by Lave and Wenger [6].ELT focuses on the individual student's experience of learning via a hands-on approach where each student is an individual 'do-er and maker' in the project group. The student works both collaboratively and cooperatively within their team, but also with the teaching staff. Though not intrinsically a part of ELT, we attempt to use the technical communication assignments (websites and presentations) as a pathway for students to reflect on what they have learned and why it was important in the scheme of the project.

Informed by SLT, we designed the program to comprise: (a) a community of practice which contributes to learning – the community is composed of the students and staff in the full program, but also at the individual project group level ; (b) learning which occurs in the context of the environment students are in – our makerspace teaching lab immersed students with the tools, technologies, and techniques needed for learning; the tools alone do not improve learning, they are held within a coherent learning approach that is both hands-on and minds-on [7]; c) a learning community composed of multiple levels of expertise to collaborate with and to engage learners – our teaching staff were giving the students continuous formative feedback on their design and gave just-in-time mentoring; and (d) experts, in the form of teaching advisors in our case allow for learning to happen.

This development of the program was heavily influenced by Delagrammatikas' work at other institutions focused on Human-Centered Design (HCD) [8]with an emphasis on inventorship. The use of HCD has become increasingly visible in undergraduate engineering curricula in recent years, with particular emphasis on IDEO's contribution to the understanding of this practice [9]

Prior author work at the Cooper Union [10], examined the influence of guided makerspace-style activities on students' perception of skill mastery and found an increase in student self-efficacy in technical skills, increased depth of knowledge of the problem they were trying to solve, and a perceived better understanding of what engineers do. Related out-of-school-time experience that informed the creation of our program have elements of physical prototyping, but no HCD approach explicitly stated, include programs at New York University [11], North Carolina State University [10], and Columbia University [12]. Numerous sources that have also shown the positive effects on self-efficacy, career awareness, and STEM-identity [13] illustrate the importance of such programs to a generation of students for which STEM careers are on the rise.

Following, in this paper, we will share our program curriculum with a step-by-step guide for student-led project ideation and team selection to develop "Tech for Good" along with evaluation findings.

3. Curriculum and Student activities

Students were tasked with designing, building, and evaluating a solution to a problem that they feel is important to society and that has the potential to improve the lives of others. Students were guided through a technical and professional skill curriculum to support their project development as seen in Table I.

TABLE I Summary of Program Curriculum

Week	Session Focus	Tech Skills	Project Development Tasks
1	Design, Prototype	CAD, prototyping with 3D printing, circuits, breadboards, microcontrollers	Ideation sessions, team formation, problem formulation, decomposition, and screening methods. Problem Formulation/Proposal: Tech Presentation 1 and 2
2	Prototyping, Testing	Soldering, Electronics	Prototyping, testing plan, build, test. Tech Presentation 3 and 4
3	Testing, Refining, Presenting	During flex time: power tools, advanced 3D printing, laser cutting, CNC Router, programming, soldering	Iterate, Test, Final Refinements. Website and video production. Practice presentation and final presentation.

This curriculum closely parallels the Seven Key Characteristics of Integrated STEM proposed by Roehrig, et al [14] which are: 1) focus on real-world problems - using the UN Sustainable Development goals as a foundation, 2) engagement in engineering design - students followed a systematic method toward problem-solving, 3) context integration - incorporating voices of those who would ultimately benefit from their technology, 4) content integration, 5) engagement in authentic STEM practices, 6) twenty-first century skills - such as technical presentations, project management methods, and e-portfolios, and 7) STEM careers - through our lunch-time talks with professionals in the fields.

3.1 Student project ideation

The group of twenty-nine rising junior and senior students, representing 21 U.S. high schools, were guided through an idea brainstorming phase where they were asked to identify issues or problems in society that could be helped or solved with technology. Students generated a wall of ideas, with over three hundred ideas written on brightly colored sticky notes. For the initial ideation round, students were asked to think of societal problems without the assistance of their phones or computers. After they seemed exhausted thinking on their own, with 5-10 ideas each, they were next directed to use available resources to gather ideas. Facilitators suggested that students review UN Sustainable Development Goals and explore global grand challenge lists.

In the third ideation phase, students were guided to use generative AI applications and to record and share their iteration process in prompting. The decision to support the exploration of product ideas with ChatGPT was not made lightly. Aligned with recommendations of educational researchers like Hiterer and McGourty [15], we wanted to empower students to confidently use novel technology to help them discover innovative ideas. We framed generative AI as another resource in the engineer's/designer's toolbox, making sure to discuss risks of sourcing ideas from ChatGPT including patent infringement, plagiarism, and a potential for an echo chamber [15].

Following idea generation, the sticky notes were organized into themes and digitized. Themes include Education; Consumer Products; Electronics, Accessibility/Human Health/Wellness; Energy/Environment; Aero/Automotive; and Other as seen in Table II. Next, students reviewed the list of ideas with a focus on scope and feasibility. Each student selected their top 3 ideas that they considered within reach given the workshop resources available to them and the limitation of a 3-week project. From the cumulative favorite ideas list, we revised the themes list to plant/crop monitoring/care, food availability/storage, water filtration/storage, adaptive tech, safety products bike/auto/home, and health care services.

TABLE II Examples of student ideas organized into themes.

Themes	Societal issues with potential tech solutions
Education	VR/AR simulations to help students visualize abstract concepts. A toy for kids that encourages them to do homework
Consumer Products	Smart bike with turn signals and brake lights Device that cuts down glare while driving
Electronics	Piezo electronics to harness energy from keyboards. Pest detection system
Accessibility/Human Health/Wellness	How to make everyone understand sign language

	Make walking upstairs easier in historic buildings where structural changes cannot be made. Encourage teeth brushing with interactivity
Energy/Environment	Detect early signs of algal blooms. Air filtering for busy streets E-waste sorting machine
Aero/Automotive	Car cooling device without leaving car on Distribution of electric car charging stations

3.2 Building teams

The next challenge was organizing the group of twenty-nine students into teams of 4-5 so that each student felt a sense of agency. We asked students to prioritize their area of interest by selecting their "top 3" themes. We labeled 6 tables, each with one theme. Students were asked to sit at the table with their top thematic directions. Teams were asked to review the project ideas related to their theme and discuss possibilities. After 10 minutes, students were invited to visit the table of their second-choice theme if they wanted to explore other options. With instructor and TA guidance, groups negotiated their "problem to solve." There was one team of ten interested in safety devices and we split them into two teams. There was another team of six and we asked that one team member join another team, but they campaigned to stay together. At the end, there were 6 teams, and each team agreed on a shared direction.

3.3 Technical and Professional Skills curriculum to support projects

Students were introduced to the engineering design process, Fig. 1, which was shown at the start of every day and groups were mentored by the teaching staff on how to maintain lockstep with this process. This gated process, in which there is a clear distinction between the design phase and the solution phase, was particularly helpful in reinforcing timelines with students. The objective was to produce a prototype as quickly as possible before they could return to the Design Analysis phase. In so doing, they were given the time necessary to thoughtfully reflect on their initial understanding of the design problem and then iteratively improve on a solution using the new knowledge they gained from the Solution phase.

Students were guided through demonstrations and hands-on activities with CAD, 3D printers, circuits, breadboards, microcontrollers, and soldering. Instructors and TAs were present in the workshop to support and supervise students as they conducted prototyping and testing. Teams could get training and explore additional tools in the workshop as they needed them including the use of power tools, advanced 3D printers, laser cutters, and CNC Routers.

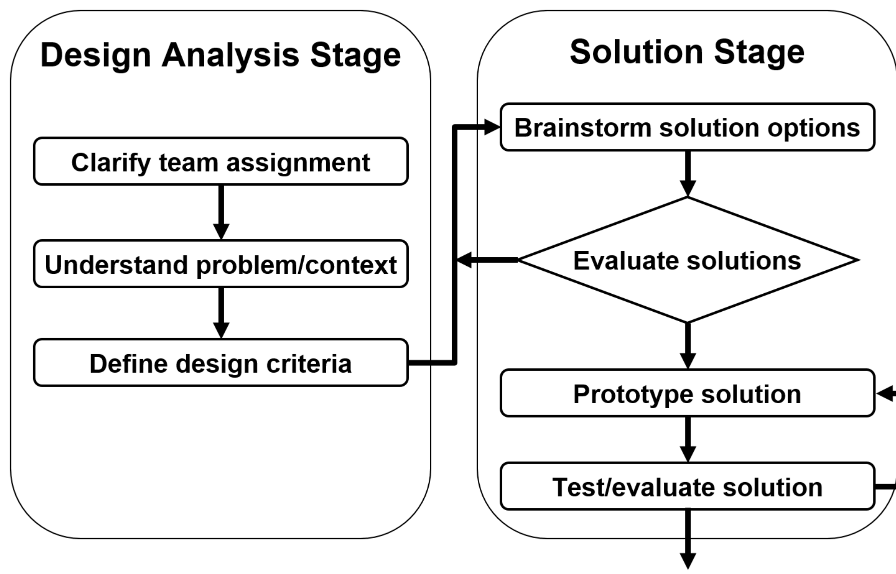


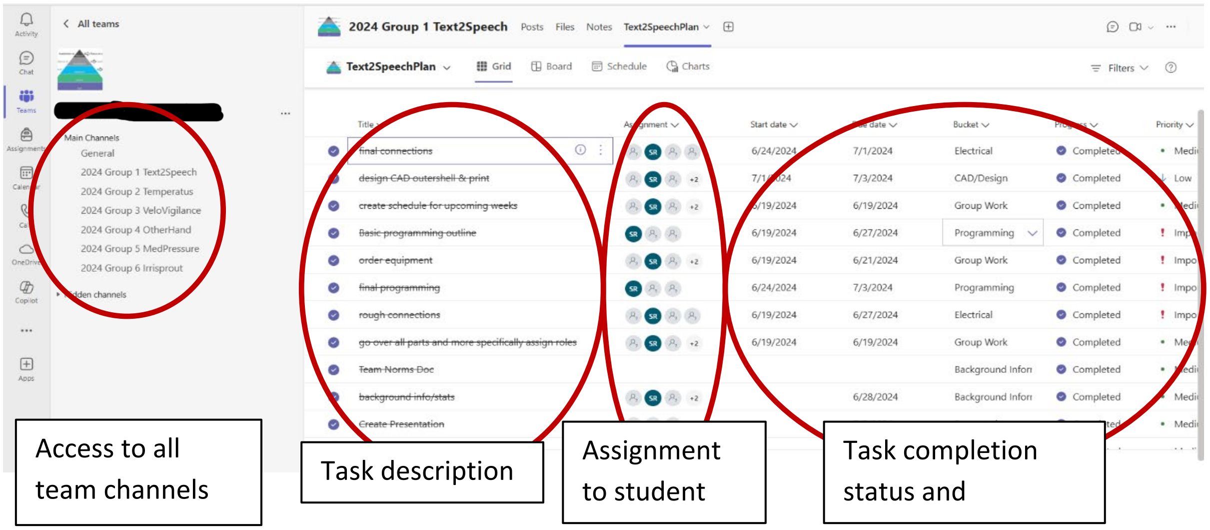
Fig. 1: This conceptualization of the design process that was revisited throughout this program. This diagram, adapted from [16].

In-class sessions also provided instructions on professional skills including a team norms activity, introduction to Kanban project management tools, and discussions for time management, task management and note taking. Student teams conducted task management through checklists within Microsoft Teams Task Planner organized by either cooperative and individual assigned tasks, see in Fig. 2 (a), or along the decomposition lines of the respective projects, as seen in Fig. 2 (b).

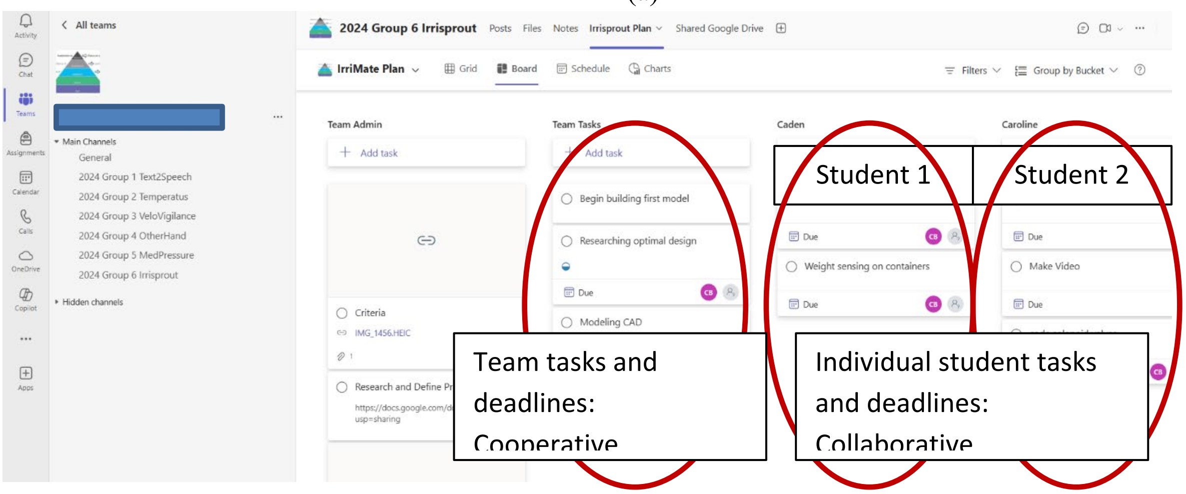
We invited eleven guest speakers, each who joined us after lunch one day to share about their science/engineering career journeys and expose students to the range of science and engineering professions including mechanical engineers, entrepreneurs, roboticist, polymer scientists, education researchers, and science/engineering communication specialists.

3.4 Executing Projects

We introduced and continued to revisit the Engineering Design Process including: 1. Problem formation, 2. Defining design criteria and constraints, 3. Brainstorming solution options and evaluating them, and 4. iterating through prototypes, shown in Fig. 1, testing, and evaluating iterative designs. Students were guided through an ideation process where the quantity of ideas was more important than their initial feasibility assessment. From these initial ideas that were written on sticky-notes, students better understood the functional needs of their intended design, which then led to a clustering/decomposition exercise, as seen in Fig. 3 (a).



(a)



(b)

Fig. 2: Two examples of how the student teams implemented Kanban boards. (a) Some teams use them as progressive checklists (b) while other teams used student task buckets.

(a)

(b)

Fig. 3. (a) Examples of ideation, decomposition, clustering, and morphing (b) and Pugh screening and scoring.

Fig. 4. Sample design schematics for prototyping of student projects.

This step allowed students to coalesce subsystems within their design that offered related functionality to the full system. They were then able to 'mix-and-match' subsystem-level solutions (known as morphing) in preparation for Pugh screening and scoring against each other as seen in Fig. 3 (b). Each team produced original technology, described in Table III with representative photos in Fig. 4, to help overcome a societal issue they deemed important. To accompany their designs, students produced a webpage and YouTube video introducing their project to the public. These e-portfolios are available to the public through the program website.

TABLE III List of student projects

Project Name	Description
Irrisprout	An app-controlled household-scale irrigation system that adjusts output based on measured soil conditions.
OtherHand	A prosthetic that is not only functional but cost-effective for people with partial-hand loss.
Text2Speachy	A text-to-speech device made to assist those who are visually impaired and struggling to read.
MedPress Embrace Mobility	An adjustable wrap for the wrist and thumb joints of the hand that uses pressure and heat to combat arthritis pain.
Temperatus	An automated cooling device that will initiate when surrounding temperatures reach a certain level, cooling the environment well before dangerous temperatures can occur.
VeloVigilance	A helmet that displays turn signals and informs users of nearby objects.

4. Research and Evaluations Methods

All program participants were asked to participate in the study with methods guided by Institutional Review Board approved protocol 2024-0521. Of the 29 students who participated in the summer program, 12 provided assent and parental consent to participate in the research and evaluation of the program. The mixed methods evaluative approach (n=12) investigated the students' perceived gains in technical skills, professional skills, engineering interest, engineering identities, careers awareness, and career interest. Data was collected from program applications, pre-post skills self-assessment surveys, Pre-post program evaluation surveys, and semi-structured interviews.

In the program applications, students shared their demographic information and their experience with design/engineering projects. In the pre/post skills self-assessment, students rated their experience level with each of the following mechanical and technical tools: CAD, 3D printing, laser-cutting, hands tools, power tools, machining, circuits/breadboards/soldering, microcontrollers, and instrumentation (i.e., thermocouples, pressure transducers). And professional skills or project experience with: report writing, oral presentations, statistical analysis of data, problem identification/problem formulation, creative ideation of design alternatives, project management tools (i.e., Gantt chart, Kanban board), research literature review, conflict resolution, time management, website creation. Within the pre/post program evaluation survey students about their interest in science and engineering, what they know about engineering careers, and if they see themselves pursuing engineering in school or jobs as seen in Table IV. A subset of survey items were repurposed from prior studies [8] and organized into themes, but did not undergo validation or factor analysis. To analyze the difference between pre and post assessments, paired t-tests were used to compare each item.

TABLE IV Sample items from pre/post program evaluation organized by measure.

Measure	Examples
Engineering Interest	I enjoy learning new ideas about engineering I like to see how things are made. I get excited to learn about new discoveries.
Engineering Identities	I think of myself as an engineering person. My friends/classmates think of me as an engineering person. My teachers think that I am good at engineering.
Career Interest	I am interested in a job where I will design new things. I am interested in working in a career that allows me to use engineering related skills. I intend to pursue an engineering internship or research project.
Career Awareness	I know about different kinds of engineering jobs. I know where to find information about engineering jobs. I know the steps to take to get an engineering job.

During the interviews, one researcher met with each student in a recorded online session. For some interviews, the parent(s) of the student were present or in the background. Interviews lasted approximately 30 minutes and transcripts were autogenerated and edited for errors and to remove identifying statements. During the interview, the researcher discussed the pre/post evaluation and assessment data for the student (application, pre-post skills self-assessment surveys, pre-post program evaluation survey) and highlighting any quantitative changes between pre and post answers. Students had a chance to revise their ratings, clarify any written responses, and add more detail to their answers. Additional interview questions included:

1. What would you consider as your greatest achievement during the STEM Academy experience?
2. This year’s program theme was “Tech for Good: Design, Build, and Test a solution to a problem that you feel is important and that has the potential to improve the lives of others. Do you think this goal was achieved? Do you feel like you have the ability to change the world through your efforts? Describe why or why not?

3. Did you have any fears or concerns about attending the program? Did they get resolved? And if so, how did you overcome those concerns/fears?
4. Did you learn about any science or engineering jobs that interested you? And why?
5. What advice would you give a student who was going to sign up for STEM Academy next year?

The qualitative analysis was guided by protocols in Creswell [17] Prior to coding, the students' interviews were transcribed, de-identified, and assigned pseudonyms. One researcher [first author] was responsible for coding the interview transcripts.

5. Results and discussion

Pre/post-measures quantitative findings highlight increases in hands-on skills, understanding of the design process, and awareness of science/engineering careers. Post-program interviews illuminate student understanding of teamwork, technical communications, and project management.

5.1 Participant demographics

In the self-reported demographics, 67% (8) of student participants identified as female and 33% (4) as male. For race, 75% (9) identified as "Asian, Asian American" or "mixed white and Asian" 25% (3) identified as "White, Caucasian". While there were a few students in the program who identified as Latino or Hispanic and/or African American or Black, these students did not elect to participate in the research. Based on reported parent and grandparent education levels, 17% (2) of student participants would be considered first generation college students and 33% (4) would be considered first generation graduate students if they continued into graduate studies.

5.2 Technical skills development

On a 5-point Likert-type scale with 1 representing "little to no experience with" and 5 representing "expert level", many students began the program indicating that they had extensive mechanical and technical experience. Statistical analysis was conducted with StataNow/SE18.5. Skewness/Kurtosis tests and Shapiro-Wilk tests indicated a non-normal distribution of data for the Likert-type data. Pre and post-test paired means were compared using Wilcoxon signed-rank and rank sum tests.

Pre-program self-reported experience levels for CAD, 3D printing, power tools, and hand tools demonstrated that students already had some comfort with these skills. We will explore the skills with the greatest increase in experience level. For example, for microcontrollers, 92% (11) of students started the program feeling like they had below average experience levels, but following the program, 83% (10) students reported increased experience levels. As seen in Table V, there were statistically significant increases in self-reported comfort with CAD, 3D printing, laser cutting, microcontrollers, and circuits/soldering. Overall, students concluded the program still lacking confidence with machining and instrumentation, two areas with limited curricular attention.

TABLE V Self-reported pre/post experience levels for technical skills (n=12)

	Pre-program				**Post program**						
Item	**Mean**	**Std dev**	**Min**	**Max**	**Mean**	**Std dev**	**Min**	**Max**	**Diff**	**P-value**	**z-score**
CAD	2.58	1.44	1	5	3.42	1.00	2	5	**0.83***	0.03	-2.42
3D Printing	2.17	1.34	1	4	3.42	0.79	2	4	**1.25***	0.01	-2.75
Laser-cutting	1.50	0.80	1	3	2.67	0.78	1	4	**1.17***	0.01	-2.75
Hands tools	3.50	0.90	2	5	3.67	0.89	2	5	0.17	0.63	-1.00
Power tools	2.83	1.34	1	5	3.33	1.23	1	5	0.50	0.06	-2.23
Machining	1.33	0.65	1	3	2.00	0.85	1	3	0.67	0.10	-1.85
Microcontrollers	1.50	0.67	1	3	3.42	1.31	1	5	**1.92***	0.00	-2.97
Circuits/soldering	2.08	1.31	1	5	3.75	1.54	1	5	**1.67***	0.01	-2.58
Instrumentation	1.25	0.62	1	3	1.75	1.06	1	4	0.50	0.13	-1.99

*Indicates p values less than 0.05

During the interviews, students reviewed the list of technical skills addressed in the program and offered a few more of their own that they considered part of their development. Samual, for example, shared about his previous experience with Arduino microcontrollers and his gained confidence in CAD, circuits, and soldering. He shared, [prior to the program] "I never actually used soldering skills on an actual project of my own." Review other examples of student reflections on their technical skills before and after the program in Table VI.

TABLE VI Representative sample participant interview data for technical skill development

Participant Pseudonym	Grade (rising)	Gender	Race/ Ethnicity	Project Name	Participant reflections
Samuel	Senior	Man	White, Caucasian	Irrisprout	Previous experience with microcontrollers. Gained confidence with CAD, circuits, and soldering.
Sophie	Senior	Woman	White, Caucasian	MedPress	Previous CAD experience. increase in 3D printing, microcontrollers, circuit boards

Nicolas	Senior	Man	Asian American	Velo Vigilance	Previous programming experience. He reemphasized learning about circuits and Arduino microcontroller
Solani	Junior	Woman	Asian American	Velo Vigilance	She gained comfort with 3D printing; laser cutting, microcontrollers

5.3 Professional skills development

On a 5-point scale with 1 representing "little to no experience with" and 5 representing "expert level". Students expressed moderate levels of experience with many of the professional skills prior to starting the program. They reported increased experience levels with website creation, statistical analysis, use of project management tools, problem formulation, and creative ideation of design alternatives seen in Table VII.

TABLE VII Self-reported pre/post experience levels for professional skills (n=12)

	Pre-program				**Pre-program**						
Item	**Mean**	**Std dev**	**Min**	**Max**	**Mean**	**Std dev**	**Min**	**Max**	**Diff**	**P-value**	**z-score**
Report writing	3.42	0.9	2	5	3.5	0.67	3	5	0.08	1	-0.13
Oral presentations	3.67	0.65	3	5	4	0.43	3	5	0.33	0.13	-2
Statistical analysis of data	3	0.74	2	4	3.58	0.51	3	4	0.58	0.13	-1.74
Problem identification	3.58	0.67	3	5	4	0.74	3	5	0.42	0.13	-1.89
Problem formulation	3.25	0.62	2	4	4	0.6	3	5	0.75	0.02	-2.61
Creative ideation of design alternatives	3.42	0.67	3	5	4.08	0.67	3	5	0.67	0.06	-2.14
Project management	2.5	1	1	5	3.5	0.8	3	5	**1.00***	0.01	-2.77
Research: Literature review	3	0.6	2	4	3.25	0.62	2	4	0.25	0.51	-1
Conflict resolution	3.75	0.75	3	5	3.58	0.67	3	5	-0.17	0.63	1
Time management	3.67	0.89	2	5	3.58	0.79	3	5	-0.08	0.94	0.4
Website creation	3	1.21	1	4	3.58	0.67	3	5	0.58	0.15	-1.62

*Indicates p values less than 0.05

During the interviews, students reviewed the list of professional skills addressed in the program and offered a few more of their own that they considered part of their development. Sophie shared about her improved project management and oral presentation skills " I remember the 1st presentation I did compared to the final. I think it was a pretty drastic [change] for me, at least." Review other examples of student reflections on their professional skills before and after the program in Table VIII.

TABLE VIII Self-reported pre/post experience levels for professional skills during interview

Participant Pseudonym	Participant reflections
Samuel	"We put a lot of work into preparing the presentations; it looked pretty polished by the end."
Sophie	Increased confidence in project management and oral presentation skills
Nicolas	Prior to the program, he expressed confidence in time and task management. From the program he gained skills in creative ideation for design alternatives
Solani	Gained confidence in project management; website creation, teamwork

5.4 Engineering Interest

Students reported their pre- and post-program perceptions on a 5 point scale with 1 representing “strongly disagree” and 5 representing “strongly agree” on three items related to engineering interest as seen in Table IX. All three measures revealed high scores before and after the program and there was no statistically significant change in interest level.

5.5 Engineering Identities

Students reported their pre- and post-program perceptions on a 5-point scale with 1 representing “strongly disagree” and 5 representing “strongly agree” on three items related to engineering identities as seen in Table IX. All three items revealed moderately high scores before and after the program with a statistically significant increase in student’s perceptions of their peers and teachers seeing them as engineers. In a few cases, students shared that the program experience influenced or solidified their intention to pursue engineering in college or as a career. Sophie shared “I think the project really helped me see what I wanted to do, sort of in the future for myself.” Students were asked if they felt their project satisfied the program goal to design “tech for good”. Some students focused on the fact that they didn’t produce a fully functional prototype and considered their design a failure as a result like in Nicholas quote “Not really [we didn’t satisfy the goal], "We were like, no one's gonna wear this [helmet], it's pretty ugly…We conceptually came up with a useful idea but we didn't get to complete it.” Other students recognized that their concept was “tech for good” and with further iterations, the goal would be fully realized. To illustrate this point with Sophie’s example “"I think our product is a hundred percent fit that criteria [tech for good]." I don't think we could have picked a project that was more oriented towards the betterment of society. What my dad says is find a need and fill it. That's his big motto."

TABLE IX Participant pre/post scores for interest level for engineering, engineering identities, career awareness and career interest (n=12)

	Pre-program				**Post program**						
	Mean	**Std dev**	**Min**	**Max**	**Mean**	**Std dev**	**Min**	**Max**	**Diff**	**P-value**	**z-score**
Engineering Interest											
I enjoy learning new ideas about engineering.	4.17	0.72	3	5	4.42	0.79	3	5	0.25	0.5	-1.04
I like to see how things are made.	4.5	0.52	4	5	4.67	0.49	4	5	0.17	0.63	-1
I get excited to learn about new discoveries.	4.58	0.51	4	5	4.33	0.65	3	5	-0.25	0.63	1
Engineering Identity											
I think of myself as an engineering person.	3.42	1	2	5	3.83	1.03	2	5	0.42	0.06	-2.24
My friends/classmates think of me as an engineering person.	3.33	1.23	1	5	3.75	1.06	2	5	0.42	0.19	-1.66
My teachers think that I am good at engineering.	3.25	0.97	1	4	3.58	0.9	2	5	0.33	0.13	-2
Career Awareness											
I know about different kinds of engineering jobs.	3.5	1.09	2	5	4	1.13	2	5	0.5	0.06	-2.23
I know where to find information about engineering jobs.	3.08	1.38	1	5	4.33	0.65	3	5	**1.25***	0.02	-2.43
I know the steps to take to get an engineering job.	2.75	1.06	1	5	3.92	0.9	2	5	**1.17***	0.02	-2.59
Career Interest											
I am interested in a job where I will design new things	4.42	0.51	4	5	4.75	0.62	3	5	0.33	0.22	-1.63
I am interested in working in a career that allows me to use engineering related	4.25	0.87	3	5	4.25	0.75	3	5	0	1	0
I intend to pursue a science or engineering internship or research project	3.67	0.98	2	5	4.33	0.98	2	5	0.67	0.17	-1.44

*Indicates p values less than 0.05

As a follow-up question, they were asked if they believed they had the capability to change the world through their work. Most students believed they gained the ability to improve the world through their designs, emphasizing that they can accomplish much more when working on a team. Samuel reflected "I do have the capabilities. And everyone on the campus [has the] capability to come up with something that people help the world in some way, no matter how small it may be." Similarly, Solani shared “After going through this experience, I think I have the ability to change the world- designing another project. [ ] I think I would be able to do it by myself this time… either with a team or independently.”

5.6 Careers Awareness

Students reported their pre- and post-program perceptions on a 5-point scale with 1 representing “strongly disagree” and 5 representing “strongly agree” on three items related to engineering career awareness seen in Table IX. All three measures revealed high scores before and after the program and all items showed statistically significant changes indicating students perceived confidence in understanding the wide array of engineering-related careers and steps needed to pursue these fields following the program.

Many students were surprised by the importance of collaborative teams both in their own projects and in the professional examples they learned about from visiting scientists and engineers. When asked which sessions students considered “career related” over half of the students recalled one faculty presentation that was focused on “career advice to my younger self” and one session of engineering career explorations delivered by an institutional career counselor. The students did not acknowledge the nine other guest speakers who joined us after lunch each day to share about their science/engineering career journeys. While these guest talks did help students recall more types of engineering, they didn’t see them as “career talks” like we had intended. Of the guest speakers, students shared fond memories of interacting with a recent graduate and entrepreneur who shared about their product design journey.

5.7 Career Interest

Students reported their pre and post-program perceptions on a 5 point scale with 1 representing “strongly disagree” and 5 representing “strongly agree” on three items related to engineering career interest seen in Table IX. All three measures revealed high scores before and after the program and no changes are statistically significant.

5.8 Research Limitations

The findings in this paper may be specific or generalizable to closely related programs and student demographics. There are a couple areas where we specifically see the data a limited.

We recognize that the sample size of 12 is rather small. While we had 29 student participants in the summer program this year, only 12 provided parent consent and personal assent to participate in the evaluation study. We also recognize that the racial/ethnic diversity of the research participant was not representative of the overall program participants or that of our local school district. We do not know why some students chose not to participate, but we intend to introduce the research project earlier in the student experience and make the purpose of the surveys and interviews clear to the students. If we are more successful recruiting diverse students (by race and ethnicity) in the future, we would like to compare the program experience using population demographics and intersectionality.

We recognize some mismatch in the triangulated quantitative and qualitative data and want to explore ways to minimize the variation between research methods. For example, student reflected during the interviews that they had a much deeper understanding of time management following the program, but their qualitative scores decreased from pre to post test. Similarly, there was a statistical increase in career awareness in the quantitative scores, but several students said that there were only a couple career-related sessions during the program. The students didn't consider the engineering guest speaker series as career exposure. We intend to emphasize and call out these sessions as "career exposure" in future to add the metacognitive element.

6. Conclusions and future directions

Students engaged in teamwork, project management, and technical communication thereby mimicking the practice of professional engineers in the areas of habit of mind while also achieving the necessary proficiency in technical skills to complete their projects. Pre/post-measures quantitative findings highlight increases in technical and professional skills and awareness of science/engineering careers. Post-program interviews illuminate student understanding of teamwork, technical communications, and project management. Many students were surprised by the importance of collaborative teams both in their own projects and in the professional examples they learned about from visiting scientists and engineers. The summer program reinforced student interest in STEM majors and careers with enthusiasm for "design for good."

Based on student feedback and evaluation findings, we anticipate making several changes to the summer program in future years.

1. We recognize that many students within our study already had extensive experience with design and maker spaces and most pursued the summer opportunity because they already had strong engineering interest and college/career intention. We are considering recruiting a younger group of students and lessening the expectation for prior experience to allow for greater impact and positive influence. An additional emphasis is to actively recruit from

high schools within a closer proximity to our institution where we could attract students from less-resourced schools.
2. Based on discussions during the student interviews, we will modify instructor/TA language to address a couple misconceptions. We will specific language to support student exploration of design iteration and failure. Some students were disappointed that their final prototype was not fully functional. We see an opportunity reinforcing the need for guided failure to gain new knowledge for subsequent design iterations. We will also reframe the guest engineering talks as career explorations so that students are more likely to connect the experience with possible future careers.
3. We also intend to modify our schedule from 5 days a week for 3 weeks to 4 days a week for 4 weeks thus allowing a little more time for students to process new knowledge and skills. A longer program, along with keeping more low-fidelity prototyping materials in stock, will help us handle the logistics of inventory and lead times for supplies. Having more tools and inventory at the students' immediate disposal would also reinforce the experiential learning element of the program, whereby just-in-time lessons can be given by the teaching staff (or fellow students) on a specific learning objective through concrete, physical application.

Ultimately, we found that applying human-centered design and creating an community focused environment with student agency were effective approaches to garner student engagement , skill development, and career exposure. We offer this curriculum, or elements within, as a framework for others to adopt or adapt.

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