Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025 ASEE
Paper ID #48226

BOARD # 218: Transforming a University-Level Experiential Learning Engineering Course into a Comprehensive Pre-College Summer Program (Work in Progress)

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ABSTRACT

Pre-college summer programs can provide K-12 students with valuable experiences that reflect the rigorous environment of higher education. Summer programs focused on Science, Technology, Engineering, and Mathematics (STEM) allow students to engage with advanced coursework materials at the university level to obtain a better understanding of the STEM field through hands-on practical learning. In addition, summer programs provide a foretaste of university academic life to K-12 students through experiencing instructions at a college campus. In this Work in Progress Study, we present the initial development of a comprehensive pre-college two-week engineering summer program for high school students. The summer program consisted of two main components: project-based learning and student exposure to professional development opportunities.

The experiential learning project was developed and adapted from a lower-division engineering course at a public institution, where students design, build, and test an autonomous rover to traverse a course and perform color recognition. The university-level coursework was modified to suit high school students while emphasizing critical course learning outcomes. Student learning outcomes include developing an understanding of the engineering design process, learning fundamental multidisciplinary technical skills, completing a project in teams, and gaining experience in technical communication. Due to the program being directly adapted from a lower-division experiential learning course, it provided the high school students with a more relevant college coursework-based experience.

In addition, students attended a series of educational and professional development seminars, including college preparation, engineering career pathways, research center tours, and demonstrations from members of the university research community and local engineering community. Exposing students to relevant engineering workshops allowed high school students to be motivated and inspired by different learning opportunities and to understand potential applications of their degrees in future careers. We assessed the success of the program implementation through a post-camp survey to all student participants, specifically on student learning outcomes of understanding design and fabrication, as well as the effectiveness of the professional development seminars. Preliminary survey results from the pilot group demonstrated that exposure to the experiential learning project in the program benefited the students' understanding of engineering and positively impacted their confidence and interest in design and fabrication. Based on the survey results, a path forward is discussed to improve the curriculum for future offerings of the program.

Introduction:

STEM K-12 educational summer camp programs expose students to potential educational paths that they can pursue in higher education [1]. This exposure is proposed to be highly motivating for students, as it is designed to provide them with deep insights into the educational opportunities available at universities [1, 2]. Students participating in K-12 educational summer camp programs often come into the program with varying degrees of knowledge on the topics; therefore, developing the program to be inclusive to all levels of experience is important. This work in progress manuscript discusses the development, implementation, and impact of an engineering experiential learning high school summer camp at a public university setting. The comprehensive program aims to offer participants university-level academic experiences while introducing them to various post-bachelor engineering career pathways. By immersing students in a collegiate environment, the camp intends to bridge the gap between high school education and higher learning in engineering fields.

Typical STEM summer camps create new projects for high school students [2, 3, 4]. In this program, we adapted a project from a university first-year level experiential learning engineering course [5,6] to suit the skill level of high school students. This approach aimed to provide participants with a more authentic university-level engineering experience within the two-week camp duration. By tailoring a college-level project to high school capabilities, we offered students a practical preview of engineering education while maintaining an appropriate challenge level. To further enrich the overall college on-campus experience, we incorporated a series of on-campus research center visits and seminars into the program.

Moreover, traditional summer programs focus on exposing students to solely undergraduate programs. However, research has shown that introducing future career possibilities can motivate academic interest [7]. In response to this finding, we expanded our program's scope beyond academic exposure with professional development opportunities to provide students insight into practical aspects of engineering careers. This program was piloted during the summer of 2024.

Curriculum Framework and Development:

STEM Project:

The main STEM project designed for the summer program was adapted from a successful project offered in a lower-division experiential project-based learning course [5,6]. The project objective is for students to develop an autonomous rover using an arduino microcontroller that is capable of navigating a course through line tracking and using color detection to retrieve an object, as seen in Figures 1A and 1B, respectively. The university-level project requires students to work in a team to design, build, and test the rover through computer-aided design (CAD) and advanced manufacturing methods such as 3D-printing and laser cutting. The students also present their results in a technical presentation and report.

Due to the short timeline of the summer camp having a duration of two weeks and the students coming from different backgrounds, the project's main goal remained the same while the main tasks and deliverables were modified. The program had a total of nine students enrolled who self-selected into the program. Due to the pilot program having a much smaller number of students than the university course, the groups were modified to be pairs of students rather than groups of 5-7, which allowed students to participate in more roles than the standard course. Also, rather than requiring the students to design their full rover in CAD software, the staff prepared three different chassis options that featured multiple design and dimensional differences, as shown in Figure 1C, to accommodate the limited engineering experiences students might have. The students were given lessons on basic engineering topics and how different characteristics of a design can both positively and negatively impact the performance of the rover. Based on those technical lessons, the students were able to select one of three options along with one of two gear motors and wheel options. The gear motors had a different gear ratio while the wheels had a different diameter. The students were required to design, build, and test their own claw mechanism in OnShape and integrate with their chosen chassis option. The students were given the freedom to design decorations in CAD and 3D-print them to personalize their projects.

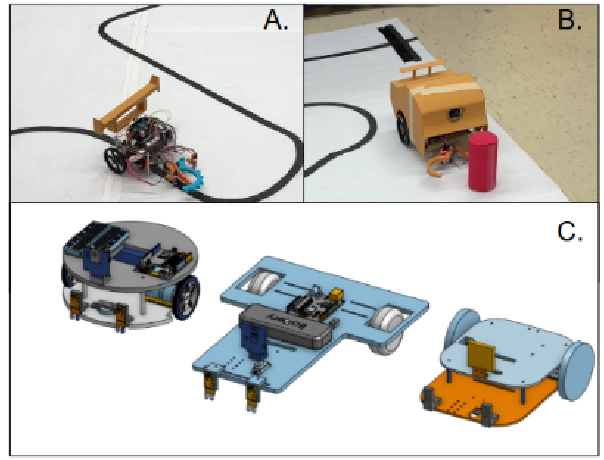

Figure 1: The summer camp project. (A): Line tracking portion of the project, (B): The color detection portion of the project, (C) The three CAD model options provided for the students to choose and have laser cut by the summer program staff

For the electrical and control system of the rover, the students were provided lessons on basic electronics along with a wiring diagram, which they interpreted with the help from the staff to assemble their circuitry. The microcontroller programming was given as a fill in the blank system in which the students had to interpret the code and finish missing sequences in the functions to complete the overall code. The students were allowed the option to implement improvements to the code. The staff would give lectures each day, and mentor the students through the project in a lab setting. On the last day of the program, the students presented the results of the project and their design decisions in a poster presentation in front of their peers, the staff, and their parents in the closing ceremony.

Academic and Professional Development:

The curriculum's overarching goal was to provide students with an opportunity to explore engineering from both an academic and professional perspective. To provide high school students with a comprehensive understanding of multiple engineering disciplines and exposure to cutting-edge research performed at the university level, the following academic seminars were incorporated into the program schedule:

- Mechanical and Aerospace Student Design Project Lab Tour
- Makerspace Tour
- Energy Fuel Cell Research Center Tour
- Introduction to Machine Learning
- Casting Center Tour

During the program's initial inception, it was noted in a literature review that many STEM summer programs lack exposure to post-university engineering opportunities, which was something that this summer program wanted to feature in addition to the traditional bachelor-level exposure. To implement this component, the program included professional development that may benefit students across multiple disciplines. Two guest speakers were invited from a local engineering company along with faculty, graduate students, and staff from the university, who provided workshops on technical communication and professional development.

Professional development seminars include:

- Industry Guest Speakers
- An Introduction to Engineering Career Paths and Research
- Project Management
- Poster Presentation and Delivery

Lastly, to make the program holistic to the college experience, we also included seminars and panels on how to be successful when applying to college and to show the students college life beyond just the engineering curriculum.

- How to Apply for College
- Undergraduate Student Panel
- Esports Center Tour
- Campus Tour

Methods:

A post-program survey was administered to the participants to better understand their views on the program and its impact on them. The questions asked about their academic goals and how the program impacted them, along with asking for their opinions on different aspects of the summer program and how it can be improved in future offerings. Finally, the survey asked how the program impacted their interest and their confidence in engineering design and fabrication.

The questions were asked both in the form of questions with the responses converted to a 1-5 Likert scale and short responses. The survey was developed partially through references to other summer program post-program surveys [3, 4, 8, 9].

Results:

The results from the pilot group show that overall the program was a success. All of the student teams were able to successfully complete the project within the given time frame of the summer camp. The student overall enjoyed the project, with students responding that the rover project has positively changed their perspective on engineering and it helped them understand the holistic process. Additionally, all students responded that they would recommend the summer program to their friends, citing that it was a great program for students with little experience in engineering and that they had the opportunity to learn about the college and what a university-level engineering program is like.

Figure 2: Metal Casting Lab Tour

The students' responses to the survey are shown in Table 1. Many students indicated that they enjoyed the academic hands-on seminars and college preparedness presentations the most. Academic seminars such as the metal casting tour (shown in Figure 2) and the career pathway presentation scored very highly along with the undergraduate panel and the "how to apply to college" presentation. The lowest-scoring presentations were the recreation center and the campus tour. Some students indicated that in future offerings they would have liked more academic and hands-on tours and presentations rather than the tours that exposed them to campus life.

	Campus Tour	Recreational Center Tour	How to Apply to College	Undergraduate Panel on College Life	Project Management/ Teamwork	Engineering Career Path and Research Seminar
Mean ± STD	3.00 ± 1.41	3.13 ± 1.45	4.25 ± 1.39	4.25 ± 0.97	3.50 ± 1.22	4.25 ± 0.97
	Student Design Project Tour	**Energy Fuel Cell Research Center Tour**	**Materials Research Lab/Metal Casting Tour**	**Makerspace Tour**	**Machine Learning/AI Seminar and Demo**	**Industry Guest Speaker**
Mean ± STD	3.75 ± 1.20	3.63 ± 0.86	4.38 ± 0.99	4.00 ± 1.00	3.88 ± 1.27	4.00 ± 1.00

Table 1: Student responses to the impact of the seminars and presentations on their experience

The students were capable of achieving the learning objectives for the program. As seen in Table 2, all the students self-assessed that they were able to achieve five out of the eight learning objectives, while two of the learning objectives had 85.7% achievement and one had 71.4% achievement, indicating the students left the program feeling overall successful. Additionally, the students indicated that they had an increase in interest in engineering design with an average score and standard deviation of 4.25 ± 0.43, where on a Likert scale, a 4 indicated that the student felt an increase in interest after the program.

Learning Outcome	Understanding the engineering design process	Using CAD (OnShape)	Soldering electronics	Programing a microcontroller	Using a Gantt chart for the rover project	Working in a team on an engineering project	Understanding the results of the Torque Test to select a gear ratio	Presenting technical information on your rover project
Student Response Rate	100.0%	100.0%	100.0%	85.7%	100.0%	85.7%	100.0%	71.4%

Table 2: Student self-assessed results for the learning outcomes

Future Work:

As a pilot program, it is recognized that various areas of the summer camp can be improved in future offerings. Possible improvements include modifications to the project and modifying the schedule to include more academic seminars and more lab time. For the project, the students reported that at times the difficulty level was too low mainly for the programming portion. To allow the summer program to be more inclusive in future offerings for various skill levels and backgrounds, more resources will be created to allow students to select the difficulty level based on their comfort level with coding. Some students may elect not to want to see any extra assistance, while others may be able to see a flowchart of the logic, and others can elect to use the fill in the blank code. This will allow students to challenge themselves, and still complete the program within a short time.

The students overall favored the seminars offered. However, they had a larger appreciation for the academic seminars, such as the makerspace or the casting center, than the non-technical sessions, such as the university's Esports Center. Some students reported that they wished that they had more time to work on the project rather than the seminars, so in future offerings, the schedule will be reevaluated to potentially accommodate their suggestions.

Conclusion:

In this work in progress study, we discuss the preliminary results of a summer camp that has been created through modifying an existing college course to be palatable for high school students. The summer camp was overall successful with the students reporting that they enjoyed the experience and that they would recommend it to others. It was shown that the project was interesting to the students and improved their interest in engineering design and fabrication, while helping them develop technical skills that are fundamental to engineering students in higher education. The students enjoyed the inclusion of professional seminars that show them the possible industry level and academic career paths. The pilot group offered suggestions for future offerings, which will be implemented to make the program more inclusive of all technical skill levels. The goal of the summer camp was achieved, and the students left the camp with a better idea of what an engineer does.

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