WIP: High School Student Experiences in Engineering: Perspectives and Insights

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***Abstract*— This work-in-progress paper explores high school students' experiences in an introductory engineering course, as part of a broader longitudinal study. The last decade has shown significant growth in K-12 engineering education. Similarly, a pre-college initiative was launched in 2018 aiming to make engineering education accessible to high school students. This study explores their experiences in engineering design projects. Specifically, we explore the similarities and differences in these experiences based on gender. The research question addressed in this study is: "How do high school students experience engineering projects, and in what ways are these experiences similar or different across genders?" Student surveys were conducted from 2019 to 2023 annually to evaluate the curriculum and understand students' experiences in early engineering classes. This study focuses on analyzing the open-ended responses of 296 high school students from 33 schools across 20 states in the academic year 2022-23, using thematic analysis. The analysis revealed a set of themes that have gender-based trends in engagement with engineering projects. Both male and female students emphasized the value of hands-on learning, collaboration, and creativity. Notably, female students more frequently explained the real-world applications, while male students showed a stronger focus on technical tools and autonomous problem-solving. Also, female students valued practical, socially relevant projects and the creative process of design; whereas male students expressed greater interest in utilizing technologies and seemed to value outcomes of creativity. These results have implications for the broader engineering community to create more meaningful and inclusive pre-college engineering experiences.**

Keywords*— *High School, Student Experience, Design Projects, Engineering Education.

I. Introduction

K-12 STEM education is vital in building 21st century skills such as creativity, critical reasoning, research and questioning, cooperation and problem solving [1]. Engaging students in STEM early on equips them for STEM degree programs in higher education [2]. Multiple reports indicate the increasing engineering and technology offering in the K-12 education [3], [4]. Despite all these efforts higher education engineering programs struggle with recruitment, retention and gender gap issues [5]. Concerns regarding the overall effectiveness of programs aimed at fostering interest and competence in STEM persists [6]. This lack of effectiveness highlights the need for better understanding how early engineering courses are perceived by the students, especially when gendered perspectives play a key role in influencing student engagement and self-efficacy [7], [8].

Teacher and peer biases, often implicit, may unintentionally limit female students' access to opportunities or support, reinforcing a cycle of underrepresentation [7], [8]. These dynamics lead to gender differences in STEM outcomes, as girls and boys often face different expectations that impact their confidence, belonging, and sustained interest. [9], [10], [11]. Among high schoolers, gendered perceptions are especially evident in engineering [12]. While interest may be similar, differences emerge in identity development, perceived competence, and encouragement [13], [14], [15]. Such concerns contribute to ongoing gender inequality in the workforce. As of 2019, the U.S. Census Bureau reported that women made up only 27% of the STEM workforce, despite comprising 48% of all workers.

Given these disparities, there is a pressing need to further explore the gendered perspectives of high school students within the pre-college engineering education context. High school is a key stage for career decisions, and understanding gendered perceptions of engineering can help design more accessible STEM interventions. This study aims to explore high school students' experiences in engineering design projects. Specifically, we explore the similarities and differences in these experiences based on gender. The research question addressed in this study is: "How do high school students experience engineering projects, and in what ways are these experiences similar or different across genders?"

II. Methods

A. Program Context

This study is part of a National Science Foundation-funded initiative launched in 2018 to demystify engineering for high school students and teachers. The goal is to introduce engineering to all students as a way of thinking and problem-solving connected to students' everyday lives. The course centers four thematic threads (discovering engineering, engineering in society, professional skills, and engineering design) which are taught through a project-based curriculum structured across four quarters [16]. Students engage in progressively complex design challenges that span local and

global contexts, applying interdisciplinary thinking, creativity, collaboration, and reflect on how engineering intersects with the world around them.

B. Research Design

Student pre- and post-surveys were conducted annually from 2019 to 2023 to evaluate the curriculum and understand students' experiences in early engineering classes [17]. The survey was designed based on Social Cognitive Career Theory (SCCT) [18]. SCCT offers a framework for understanding how students develop academic and career interests, highlighting the role of environmental factors and past experiences in shaping their decisions.

This study as a part of bigger study analyzes responses to one open-ended question from a post-survey administered during the 2022–2023 academic year: 'What did you like best about this class?' Details about the survey instrument is available in the following reference [15]. Thematic analysis was used to explore classroom experiences, with attention to gender-based similarities and differences.

The survey was administered in 33 schools across 20 U.S. states and territories, including Arizona, California, the District of Columbia, Florida, Hawaii, Illinois, Indiana, Kentucky, Maryland, Massachusetts, New Hampshire, New Jersey, New Mexico, New York, North Carolina, Pennsylvania, Rhode Island, Tennessee, the U.S. Virgin Islands, and Virginia. Informed consent procedures were followed for data collection after obtaining IRB approval from both the participating schools and the authors' institution. A total of 296 students participated in the survey. Table I presents the demographic distribution of the respondents.

TABLE I. DISTRIBUTIONS OF THE DEMOGRAPHIC DATA

Category	Subcategory	Percent (%)
Ethnicity	White	36
	Black/African American	18
	Latino/Hispanic/Mexican American	15
	Asian	20
	Mixed	7
	Other	1
	Undisclosed	3
Gender	Men	58
	Women	38
	Non Binary	2
	Non Disclosed	2
Grade	9th	21
	10th	24
	11th	17
	12th	21
	Undisclosed	17

C. Analysis

A total of 268 student responses were analyzed, including those from young women (n = 101) and men (n = 154), excluding blank responses and those from other gender identities. An inductive approach guided the qualitative analysis, with responses examined to identify similarities and differences between groups within each theme. Each response was reviewed in full, and overlapping ideas across themes were noted. Quantitative counts and percentages were calculated to support gender-based comparisons. Due to the open-ended nature of the question, many responses aligned with multiple themes.

III. RESULTS

A total of ten key themes were identified, reflecting both shared and distinct patterns in gendered responses as shown in Table II. The first four themes are discussed in detail, with a focus on gender-based similarities and differences. Brief descriptions of the remaining themes are provided at the end. Notably, many student responses reflected multiple perspectives, resulting in considerable overlap among themes. It should be noted that the survey asked students to report their self-identified gender as an open-ended question. While most students responded with "male" or "female", there were also responses including "boy", "girl", "woman" and "she". We use all these terms as we describe the results to honor student voices.

TABLE II. KEY THEMES DERIVED FROM THE ANALYSIS

Theme	Responses by young women	Responses by young men
Hands-on Learning and Projects	48 (47.52%)	84 (54.55%)
Collaboration and Teamwork	29 (28.71%)	26 (16.88%)
Creativity	29 (28.71%)	39 (25.32%)
Technology and Tools	21 (20.79%)	29 (18.83%)
Critical Thinking	17 (16.83%)	17 (11.04%)
Real-World Application	14 (13.86%)	16 (10.39%)
Problem Solving	13 (12.87%)	16 (10.39%)
Challenges and Accomplishments	8 (7.92%)	11 (7.14%)
Open-Ended and Flexible Learning Environment	7 (6.93%)	12 (7.79%)
Teacher Support	7 (6.93%)	9 (5.84%)

A. Hands on learning and projects

The theme of hands-on learning and projects emphasizes learning through active engagement. In the context of this study, this theme highlights the students' perspectives on working on real-world projects by building prototypes, experimenting, testing solutions, and applying the theoretical knowledge they have gained in class. A total of 48 out of 101 young women (47.52%) and 84 out of 154 young men (54.54%) expressed responses aligning with this theme.

a) Similarities: Responses across all students strongly emphasized the hands-on nature of the projects. Whether it's about building prototypes, working on projects, or engaging with physical materials, all students consistently highlighted the practical, tactile aspect of learning. For example,

- Young Woman: "I liked building prototypes and testing them out to see if they worked well or not."
- Young Man: "I enjoyed the builds." / "Building things and testing them."

Young men and women both mentioned enjoying the freedom allowed in the projects. They appreciated being able to approach the tasks in their own way and coming up with solutions:

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- Young Woman: "I best enjoyed the freedom to create projects and prototypes that interested me."
- Young Man: "I liked the freedom and projects we did in this class." / "I liked the autonomy during project design, and the opportunity to make things that we think are interesting at our own pace."

b)Differences: Young women more frequently mentioned the applicability of their projects to real-world issues, such as "practical projects" and "real issues." They seem to value hands-on projects that connected directly to solving realistic problems, whereas men less frequently specified the application of their projects to real-world scenarios. Young women emphasized real-world applications significantly more (25.0%) than young men (4.8%) within the context of projects and hands on activities.

There is a difference in how frequently tools and technology within the context of projects are mentioned by young men and women. Men more often (16.7% compared to 4.2% for women) mentioned specific tools, materials, and platforms (e.g., "3D printers," "CAD," "Onshape,"). This may suggest an interest in the technical tools involved in project work, reflecting an engagement with the equipment itself as part of their learning experience.

B. Collaboration and Teamwork

Collaboration and Teamwork in the context of this study refers to students' perspectives on working together to achieve a common goal, solve problems, or complete projects. Collaboration and teamwork emphasize the collective effort of students, which is especially important in engineering projects that require diverse perspectives and skill sets. This theme highlights the importance of communication, cooperation, and shared problem-solving in achieving group success. A total of 29 out of 101 young women (28.71%) and 26 out of 154 young men (16.88%) expressed responses aligning with this theme.

a)Similarities: Both groups mentioned how teamwork helped them gain new skills, whether through problem-solving, communication, or learning from others in the group:

- Young Woman: "It helped me improve my communication skills with my teammates."
- Young Man: "I liked how this class allowed me to work in groups which ultimately helped me build many skills."

Both men and women highlight the enjoyment they found in working with their peers. The aspect of fun, camaraderie, and making friends was significant to both groups in the context of teamwork:

- Young Woman: "working with friends on cool project"
- Young Man: "It was fun to create things and work with my friends."

However, many students also pointed out the challenges that exist with team work such as non-contribution by team members, conflicts and lack of collaboration:

- Young Woman: "I didn't like how some people didn't help."
- Young Man: "I didn't really dislike anything in this class but I guess some my group members not doing anything is something I'd like changed."

Both men and women appreciated the problem-solving aspect of working together. They often mentioned how their teamwork led to finding solutions, building prototypes, or developing ideas:

- Young Woman: "I enjoyed working with partners to find solutions to a given issue, then bring those ideas to life."
- Young Man: "Working with other people trying to solve problems that actually matter."

b) Differences: Young women more frequently mentioned specific aspects of collaborative work, such as "bringing ideas to life" and "making a solution that worked for everyone." This suggests they may have placed a slightly stronger emphasis on the creative and constructive aspects of collaboration. Women mentioned project-oriented aspects (33.33%), compared to men (20%).

C. Creativity

Creativity in the context of this study refers to students having the freedom to explore ideas, experiment with designs, and bring their personal innovations to projects. This theme reflects how students value the opportunity to apply their imagination and unique approaches to solving problems, rather than simply following a set formula. A total of 29 out of 101 young women (28.71%) and 39 out of 154 young men (25.32%) expressed responses aligning with this theme (Table II).

a) Similarities: Both young men and women responses emphasized the importance of having the freedom to explore and create, with both groups enjoying autonomy in projects and designs:

- Young Woman: "I best enjoyed the freedom to create projects and prototypes that interested me."
- Young Man: "I liked having the freedom to make my own decisions."

Creativity for both groups was often tied to problem-solving. They mentioned how their creative efforts were aimed at finding unique solutions to problems, whether in group projects or individual work:

- Young Woman: "I enjoyed working with partners to find solutions to a given issue, then bring those ideas to life."
- Young Man: "The ability to solve problems creatively using engineering and make solutions using our skills and creativity."

Both groups highlighted the role of collaboration and teamwork in fostering creativity. They mentioned how working in groups or teams helped generate more creative ideas:

- Young Woman: "I liked a lot of the group projects, because there were a lot of ideas going around and you were able to make a solution that worked for everyone."
- Young Man: "I liked the teamwork the most, it helped more so we didn't have such a high workload and it allowed us to cooperate and work together."

b) Differences: Young women often described their creative process in more detail, mentioning specific projects like "designing a wallet from duct tape and straws" or "exploring new problems and coming up with a solution." They seem to value the creative process itself and the freedom it provided. Altogether, 55.17% of all female responses detailed their creative process, such as designing, creating, exploring, or valuing the freedom to develop solutions. In contrast, men often focused more on the outcomes of creativity (69.23% male responses), such as " prototypes and testing our solutions" or "being able to build things in class.":

- Young Woman: " I enjoyed how I was able to experiment with engineering through a variety of different tasks such as exploring engineering in regards to space, music, water filtration, etc."
- Young Man: "I liked the golf course project as well as the prosthetic hand project because it required brainstorming ideas and building prototypes."

D. Technology and Tools

"Technology and Tools" in the context of this study refers to various engineering technologies and tools that students use to design, prototype, and build their projects. This theme emphasizes how students use modern technologies to bring their ideas to life and solve engineering problems through hands-on experiences.

a) Similarities: There was a shared interest among both young men and women in using technology and tools to design, build, and test prototypes, which is a central part of their learning process:

- Young Woman: "I liked building prototypes and testing them out to see if they worked well or not."
- Young Man: "Creating and testing prototypes."

b) Differences: Responses by men tended to mention more physical tools such as soldering or using power tools, whereas women seemed to focus equally on digital and design tools, and physical tools:

- Young Woman: "I liked the experience of learning CAD."
- Young Man: "3D printing and soldering."

E. Other Themes

While many themes emerged, the most significant are discussed above. A higher percentage of women's responses were observed as related to critical thinking, problem solving, and real-world application (Table II). In contrast, responses discussing challenges and accomplishments, open-ended learning, and teacher support were similar across both genders.

Although based on a small sample, women expressed more direct appreciation for the teacher as a mentor, using metaphors like "Master Shifu" and highlighting emotional support and encouragement. Men also valued the teacher's role but emphasized independence, time management, and problem-solving guidance. Women placed greater value on direct support from teachers and peers, enjoying collaboration and guidance. In contrast, men preferred autonomy, appreciating a flexible class structure that allowed them to take charge of their projects.

IV. Discussion and Conclusion

For this work-in-progress research paper, student perceptions of engineering were analyzed through a gendered lens to highlight key similarities and differences. Both male and female students placed high value on hands-on learning, collaboration, and creativity—indicating a shared appreciation for experiential and interactive approaches to engineering education. However, female students were more likely to emphasize real-world applications, socially relevant projects, and the iterative nature of the design process. In contrast, male students gravitated toward technical tools, autonomous problem-solving, and tangible outcomes from creative processes.

These gendered differences in emphasis offer valuable insights. Female students' focus on socially embedded engineering tasks suggests that connecting engineering to societal and community contexts may be a strong motivator for their engagement and persistence. Literature also explains that women are more likely to stay in engineering because they want their work to make a positive difference in society or the environment [19]. Meanwhile, male students' interest in technical challenges and self-directed problem-solving points to the importance of providing spaces for exploration, autonomy, and skill mastery.

Jones et al. found that boys and girls interact differently with scientific tools in educational settings, with boys more likely to engage in exploratory and assertive tool use, while girls tended to follow instructions more closely [20]. The results from this study also lean in this direction where young men were explicit in mentioning the physical tool usage.

In line with literature, young women in this study expressed more about creativity. A systematic literature review performed on gender differences in creativity reported higher creativity in women [21]. While some studies have explored gendered perceptions of creativity in engineering, there remains limited research specifically examining how young women and men perceive creativity within pre-college engineering contexts.

This study has several limitations. The analysis is based on a single open-ended question from the survey instrument. Moreover, 17% of the students did not report their current grade level. This may be attributed to a lack of clarity in the question, "*Please indicate your current year in school*," as some students interpreted it as referring to the academic year rather than their grade level. Future work will incorporate responses from additional questions to build on and contextualize the findings presented here. Additionally, the current analysis focuses on

data from a single academic year; examining data from other years is planned to explore the consistency and recurrence of these themes over time.

There are implications for curriculum designers and teachers to support students in a manner that leads to positive early engineering experiences. While the study provides useful insights, it is limited by a who chose to participate. Our future plans also include exploring SCCT models of interest development and career choice through quantitative analysis and exploring student personas [22] to further understand student needs and improve curriculum design for learning. In conclusion, this study highlights the need to adapt curriculum design and teaching methods to different student interests and supports the call for more research to create accessible and engaging learning environments.

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