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What Is Engineering? Exploring High School Students' Perspectives from a Summer Introduction to Engineering Program (Fundamental Research)

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Abstract

Engineering, both as a field of study and practice, has long been acknowledged for its vital role in addressing complex, real-world challenges through innovation, creativity, and the application of scientific principles. This qualitative descriptive study sought to explore the perspectives of high school engineering students (n= 73), focusing on their views of what engineering entails, how it is applied, and the skills and processes they associate with it. Thematic analysis of data, which encompassed student work and reflections, revealed that students conceptualize engineering as a dynamic and interdisciplinary field that integrates scientific, mathematical, and technological knowledge to address practical challenges. Central to their perceptions are themes of problem-solving and innovation, with many students emphasizing the roles of creativity and critical thinking in developing solutions. Additionally, collaboration emerged as a key aspect of engineering practice, with students recognizing the importance of teamwork in transforming ideas into tangible outcomes.

Keywords: Engineering, Pre-college Education, High school, Qualitative,

Introduction

Engineering skills are increasingly recognized as essential competencies for success in the 21st century, as they support students' problem-solving abilities, systems thinking, and capacity for innovation. In response, engineering has gained growing prominence in pre-college education and has become a focal point of national education reform efforts. Engineering was formally positioned as a core component of K–12 science learning in *A Framework for K–12 Science Education* and subsequently embedded within policy initiatives such as the Next Generation Science Standards [1].

Alongside these policy shifts, a wide range of curricula, classroom-based engineering activities, after-school programs, and summer camps have been developed to introduce students to engineering concepts and practices. Despite these expanded opportunities, the National Academy of Engineering has cautioned that although everyone is surrounded by products that result from engineering, the connection is rarely made clear [2]. As a result, increased exposure to engineering does not necessarily translate into a coherent or accurate understanding of what engineers do or what engineering entails.

As engineering becomes more deeply integrated into K–12 education, understanding how students conceptualize engineers and engineering is critically important. Students' definitions of engineering shape their engagement with engineering tasks and influence the development of their identities, interests, and long-term participation in STEM pathways [2-3]. However, decades of research suggest that many K–12 students hold narrow, inaccurate, or stereotypical views of engineers and engineering work, often emphasizing construction or repair while overlooking design, iteration, and problem-solving processes [4-5]. This literature review synthesizes research on K–12 students' perceptions and definitions of engineers and engineering, with particular attention to persistent misconceptions, developmental trends across grade levels, and instructional factors that shape students' understanding.

Background and Literature

Defining Engineering in K–12 Education

Engineering is broadly defined as a systematic and iterative process of designing solutions to human problems within constraints, drawing upon science, mathematics, and technology [1, 6]. In K–12 contexts, engineering is often operationalized through engineering design, emphasizing problem identification, ideation, prototyping, testing, and optimization [6]. Despite these formal definitions, research shows that students' personal definitions frequently diverge from disciplinary understandings, particularly when engineering instruction is limited or fragmented [7].

Scholars argue that early and sustained exposure to authentic engineering practices is critical for helping students develop accurate conceptions of engineering as creative, iterative, and socially relevant work rather than as isolated technical labor [5, 8]. Without such exposure, students' definitions tend to rely on cultural stereotypes and everyday experiences rather than disciplinary knowledge.

Students' Views of Engineers and Engineering

In elementary education, research consistently demonstrates that younger learners often associate engineering with *building, fixing, and working with machines*, rather than with problem solving or design thinking [9-10]. When asked to describe engineers, many students depict individuals who repair cars, construct buildings, or operate heavy machinery, frequently conflating engineers with mechanics or construction workers [10].

Studies using drawing-based instruments, such as the *Draw-an-Engineer Test*, reveal that elementary students often represent engineers as male, working alone, and engaged in physical labor [11]. These representations reflect broader societal stereotypes and suggest that students' early conceptions are shaped more by media portrayals and limited personal exposure than by formal instruction [11].

Importantly, research also indicates that elementary students' views are malleable. When students engage in well-designed engineering curricula that explicitly frame activities as engineering, their definitions begin to shift toward recognizing design, testing, and improvement as core engineering practices [5, 12]. These findings suggest that even brief, intentional engineering experiences can broaden young students' understanding of what engineers do.

At the middle school level, students' definitions of engineering become more articulated but often remain incomplete. Many middle school students recognize that engineers "design" or "build," yet struggle to explain how engineering differs from science or technology [13-14]. Research shows that students frequently view engineering as applied science rather than as a distinct discipline with its own epistemic practices [15].

Survey-based and interview studies indicate that a significant proportion of middle school students report uncertainty about engineering careers or are unable to describe engineering work beyond surface-level tasks [13]. This uncertainty is particularly pronounced among students who have had limited exposure to integrated STEM or engineering-focused instruction [16].

Gender differences also begin to emerge more clearly during middle school. Studies suggest that girls are more likely than boys to associate engineering with mechanical or physically demanding work, which can reduce their interest if these tasks conflict with their self-perceptions or values [17]. Conversely, when engineering is framed as collaborative, creative, and socially meaningful, girls' interest and engagement increase [18].

High school students often demonstrate a more sophisticated awareness of engineering as a profession, yet misconceptions persist. While many students recognize that engineers solve problems and use mathematics and science, they may still view engineering as narrowly technical, difficult, or inaccessible [19-20]. These perceptions can influence students' course-taking decisions and willingness to pursue engineering pathways.

Research on high school students' career perceptions indicates that those who lack authentic engineering experiences are less likely to identify engineering as a socially relevant or creative field [21]. Additionally, students from historically underrepresented groups often report limited knowledge of engineering careers and fewer opportunities to interact with engineers, reinforcing inequities in participation [22].

Importantly, exposure to project-based engineering courses and extracurricular programs has been shown to positively influence high school students' definitions of engineering, helping them recognize teamwork, iteration, and real-world impact as central features of the discipline [23].

Engineering Identity and Student Perceptions

Students' views of engineering are closely tied to the development of *engineering identity*, which encompasses interest, perceived competence, and recognition by others [19]. Although engineering identity research has traditionally focused on undergraduate populations, recent studies suggest that identity formation begins much earlier, shaped by students' perceptions of who engineers are and what they do [16].

When students hold narrow or stereotypical definitions of engineers, they may struggle to see themselves as potential engineers, even when they demonstrate strong aptitude [22]. Whereas classrooms that position students as engineers and explicitly name their work as engineering can foster positive identity development and broaden participation [12].

Instructional context also plays a critical role in shaping students' views of engineering. Research consistently shows that explicit instruction about the nature of engineering, rather than implicit exposure through isolated activities, leads to more accurate and inclusive student definitions [25]. Teachers' own understandings of engineering also matter; when teachers conflate engineering with science or focus solely on building activities, students' misconceptions are reinforced [26].

Curricula that emphasize real-world problems, constraints, trade-offs, and optimization help students recognize engineering as a socio-technical discipline that integrates creativity, ethics, and collaboration [7]. Additionally, representation of diverse engineers in curriculum materials and classroom discourse has been shown to challenge stereotypes and expand students' visions of who can be an engineer [16].

Research indicates that the perceptions and definitions of engineers and engineering held by K–12 students are frequently limited, stereotypical, and influenced by societal narratives rather than disciplinary knowledge and understanding. Furthermore, these perceptions are subject to change over time. While these views evolve with age and exposure, misconceptions frequently persist across grade levels. Instructional experiences that explicitly frame engineering as creative, collaborative, and socially relevant are essential for supporting accurate understanding and positive identity development. Addressing students' perceptions of engineering is therefore a critical component of equitable and effective K–12 engineering education.

Research Purpose & Questions

To sustain support for the inclusion of engineering in pre-college education, it is important to examine students' descriptions of engineering and how their definitions have evolved [27]. It is critical to understand how high school students perceive engineering, as this understanding can inform their career interests and help address any misconceptions they may hold. In this study, we examine students' definitions of engineering based on their participation in an engineering summer course. The following research question guides the study: 1) *How do high school students in the introductory engineering course describe and define engineering?*

Methods

Research Design

This descriptive qualitative study aims to investigate students' descriptions and definitions of engineering based on their course experiences. Qualitative descriptive studies are grounded in the principles of naturalistic inquiry, enabling examination of a phenomenon in its natural state. This methodology is well-suited for studies "when straightforward descriptions of phenomena are desired" [27, pp. 339]. The phenomenon targeted in this study is students' perceptions of engineering following their exposure to and engagement in engineering activities during the summer Introduction to Engineering Course.

Context: Introduction to Engineering Course

Students in this study are from three sections of a two week-long summer *Introduction to Engineering course* that was conducted online (two sections) and in person (one section), in two consecutive years at an educational institute located in the East coast. The total of 73 high school students participated in this course, students who were diverse in gender, ethnicity, nationality and grade level. The students from the online sections, were from across the world, including students from Africa, Europe, Asia, South America and North America. Student had completed 9th grade-11th grade, with many of the students were entering 11th grade.

The course was designed to provide high school students with a broader understanding of engineering, encompassing a range of disciplines such as Mechanical Engineering and Biomedical Engineering. Through guest lectures and group activities, students gained insights into the growing diversity of engineering fields. The course also addressed the professional ethics of engineering and evaluated the responsibilities engineers bear towards society and the environment.

Additionally, students engaged in a small capstone project, where they applied the engineering design process to create an exhibit for children aged 5 to 12 years. Upon completion of this course, students were anticipated to possess a comprehensive understanding of the engineering field, the various career paths available, the engineering design process, and the ethical considerations inherent in the profession (Figure 1).

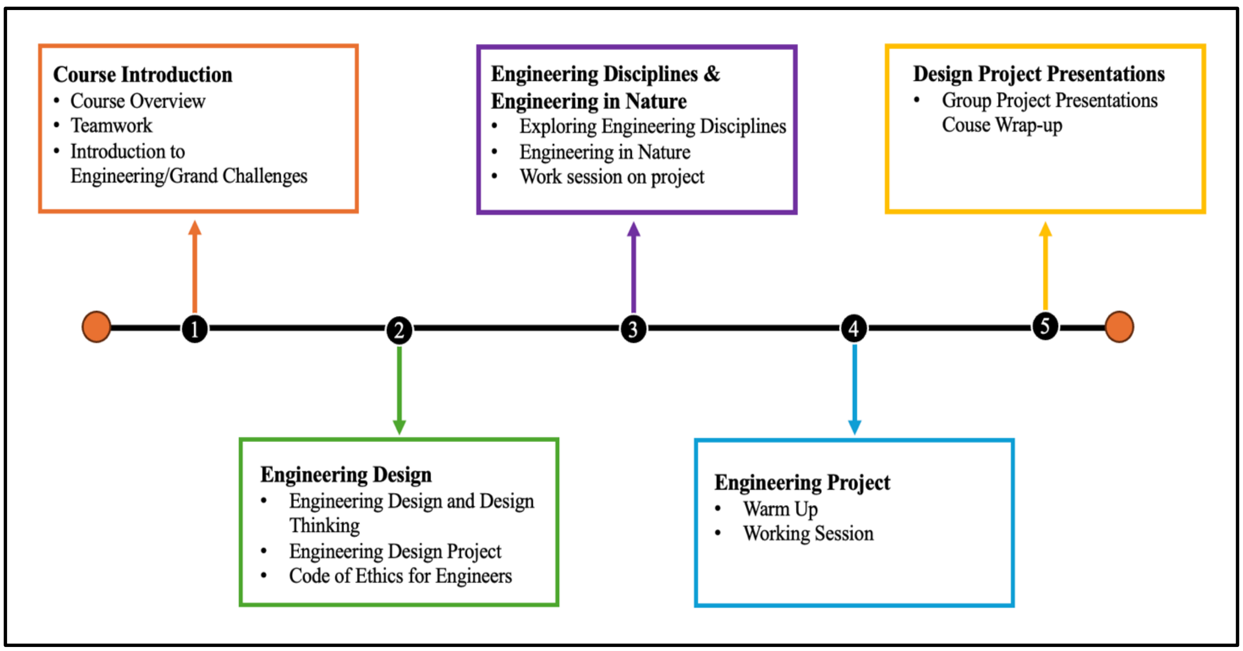

Figure 1. Introduction to Engineering Course Timeline

Data

The data sources for this student included student activities and reflections. Students engaged in various activities related to the subject matter under discussion. They viewed instructional videos to learn about diverse engineering disciplines. Additionally, they participated in a brief engineering capstone project to design an educational exhibit for children.

Throughout the week, students also completed post-reflections. These post-reflections required students to reflect on their learning experiences in class and compose a one-page reflection on the content covered. Each reflection necessitated addressing specific questions related to the subject matter and concepts acquired. In total, students completed four reflections, one at the end of each day. Along with the reflections, students each day completed a brief warm-up and/or brainstorming activity prior to the commencement of the lesson on engineering. For instance, on day one, students were asked to reflect on engineering, and on day two, they were asked to reflect on things that fascinated them about engineering (see examples in Figure 2).

Day 1. Take a few minutes to reflect on engineering and what **YOU** think engineering is…. Then, take 5 to 7 minutes to document your thoughts (or until I say stop). You can use **words**, **drawings**, **and/or pictures**. Once done, please upload your document onto Canvas. Be Ready to Share!

Day 2. Take a few minutes to reflect on the things that fascinate you about engineering…Then, please take 10 minutes to document your thoughts (or until I say stop). Think about an engineering project that you love. Think about your everyday life as well as what you learned from the media! You can use **words**, **drawings**, **and/or pictures**. Once done, please upload your document onto Canvas. Be Ready to Share!

Figure 2. Warm-up prompts about engineering.

Data Analysis

A thematic analysis was conducted on the participants' work and reflections, as it is a recommended method for descriptive qualitative studies [28-30]. We adhered to Braun and Clarke's [29] six-phase method for thematic analysis, which included familiarizing ourselves with the data, generating initial codes, searching for themes, reviewing, defining, and naming the themes, and creating the report. Although the method appears linear, we engaged in an iterative and reflective process that involved continually moving back and forth between the phases. Constant comparison, initially within each data set, was employed to consistently sort the data until a robust set of themes explaining the data was developed for each cohort. Finally, these themes were compared and consolidated into overarching themes.

Adhering to the trustworthiness criteria proposed by Guba and Lincoln [31] significantly enhanced the credibility of this study. We established credibility through the triangulation of data and researchers, which involved both data and researchers. In this instance, the data encompassed a diverse range of student activities and reflections. The inclusion of a diverse student population provided us with a broader perspective on engineering. Researcher triangulation involved multiple researchers independently coding the data, followed by group discussions to identify themes. The agreements and disagreements among the researchers were subsequently examined through in-depth conversations at various stages.

The data uncovered three primary themes: *Problem-Solving and Innovation*, *Application of Knowledge* and *Collaboration, and Creativity*. The findings elaborate on these themes, and the results of the coding process further support the claim that these perspectives are comprehensive and widely represented among the population. A limited number of student responses are included for illustrative purposes, and pseudonyms were used to maintain student anonymity.

Findings

This study's findings revealed that students' perspectives and descriptions of engineering were shaped by their experiences within the course and any personal experiences they had encountered. Students emphasized engineering's role in identifying and addressing problems. They highlighted that engineering integrates various fields of study and relies on established knowledge to tackle real-world issues. Furthermore, engineering is a creative endeavor in which imagination and design play pivotal roles in developing innovative solutions that enhance life.

Engineering is Problem-Solving and Innovation

Many students highlight the role of engineering in identifying and solving problems. Engineering is understood as a process of creative thinking, critical analysis, and iterative improvement, in which solutions are developed to enhance efficiency and effectiveness. For instance, Student 2 claimed,

> *I think engineering involves finding solutions to problems we face by utilizing the design process. Once finding a possible solution to the problem, I think engineering is manufacturing the means to make it better and create something that solves the problem and helps other people resolve the same issue for themselves. This engineered solution can constantly be improved upon by adding tweaks and improvements, which is also what I think engineering is: constantly looking at things critically and finding new ways to make the objects and tools in the world around us more efficient.*

Another student asserted that engineering is innovation, which aids in improving everyday life. Students 6, 9, and 8 asserted,

> *I think engineering is about finding ways to solve problems using previously established knowledge, skills, and research through educated trial and error. Engineering starts with finding a problem and or something that could be improved and may end with no solutions being found, but the process still shows what does not work and could also still show great ideas. Engineering is ongoing and doesn't stop once a subproblem is met; it is about solving the smaller problems that make up the larger problems, thus solving the larger problems. Engineering usually takes ideas and tries many ways of implementing them to solve problems (Student 6).*
>
> *Engineering involves brainstorming creative new ideas and bringing them to life. It is a form of innovation in which the products are ideas that make life easier. Engineers who have applied their thinking to the real world are responsible for most of the things we use in our everyday lives. To me, engineering is a thought process about how to make the world more accessible and unified in what we do (Student 9).*
>
> *Engineering is about solving problems using collected knowledge, innovation, and technology to alter the world around us, both for good and bad (student 8).*

Similarly, one student connected their experience as a means to define engineering. Student 11 highlighted that engineering is "the process of creation" that entails using "toys like Legos and different circuit devices to make designs," which they have loved doing ever since they were young.

These examples demonstrate that students perceive engineering as a creative process centered on problem-solving, innovation, and continuous improvement. It involves recognizing challenges, developing solutions, and refining them to enhance efficiency and improve everyday life. Engineering is regarded as a means of making the world more accessible, often through hands-on activities such as design and construction.

Engineering is the Application of Knowledge

A recurring theme is the utilization of science, mathematics, and technology to develop practical solutions. Students highlight the interdisciplinary nature of engineering, which integrates various fields of study and leverages established knowledge to address practical challenges. This includes mechanical and software engineering disciplines. For instance, Students 1, 3, and 7 all claimed that engineering requires the application of knowledge from other disciplines.

> *Engineering is a big major [that includes] many fields, such as aerospace engineering, mechanical engineering, and biomedical engineering. It is focused on mathematical thinking and depends on math and physics. It is one of the most crucial majors because almost everything depends on engineering (Student 1).*
>
> *I think engineering is the application of science and math, from medicine to software. For example, biomechanical engineering, software engineering, etc. I think engineering is an umbrella term for lots of different related things that are honestly fairly hard for me to define exactly in words. Still, engineering is very important because, without it, we wouldn't have cars, computers, medicine, et. (Student 3).*
>
> *Engineering is the application of thought, data, and sciences to create a solution to a problem. There are several fields of engineering, from mechanical engineering to civil engineering and even social engineering. Each of them uses data, which is then interpreted so that a solution can be created. Even innovation in engineering is a solution to the shortfalls of an object or system that may have performed the same task" (Student 7).*

Student 10 emphasized that engineering is "at its core using science and math to solve problems," and these scientific principles and mathematical methodologies are used to discern, analyze, and resolve practical challenges. In contrast, Student 14 considers engineering not just a "discipline" but also a "skill" applied to create and innovate solutions for everyday problems.

These examples demonstrate that numerous students perceive engineering as an interdisciplinary field that leverages scientific principles, mathematical concepts, and technological advancements to address practical challenges. Engineering encompasses diverse disciplines, such as mechanical, software, and biomedical engineering, each employing scientific methodologies and data-driven approaches to confront real-world complexities. Furthermore, some students conceptualize engineering as both a discipline and a skill set that fosters innovation and problem-solving abilities.

Engineering is Collaboration and Creativity

Several students highlight the collaborative essence of engineering, emphasizing the critical role of teamwork in transforming concepts into reality. Additionally, engineering is characterized as a creative discipline where imagination and design are vital in formulating innovative solutions that enhance daily life. For instance, Student 12 claimed that "Engineering requires critical thinking, teamwork, and creativity". Similarly, Student 4 also described engineering as a "collaborative problem-solving and making theories become reality.

Furthermore, students emphasize that engineering is a creative discipline that guides problem-solving approaches. Student 15 articulated, "Engineering entails the generation of creative solutions to challenges. It encompasses the generation of ideas, the formulation of plans, and the execution of physical actions. However, engineering emphasizes the mindset rather than the actions themselves." Similarly, Students 5 and 13 defined engineering as a creative process that involves the creation of tangible outcomes.

> *To me, engineering is creativity. It is creating or manifesting any and every idea that you can think of. Being an engineer does not consist of reinventing or recreating something that is presented to you. It consists of observing or pondering what has been made and how to improve it. It is about improving and enhancing anything and everything around you at all times, constantly thinking about not what is wrong, but what could be better (Student 5).*

> *Engineering is the practice of creation which can solve an issue or advance knowledge in a subject. Engineering exists in multiple forms, and many different branches of Engineering focus on different subjects and the issues within them. These branches have specific knowledge that a person may study in a class like a University, like Software Engineering. I believe engineering is crucial and is the reason why many of the issues we have are solved. Engineers also have to think critically, and this is a reason why Engineering can be difficult for some. That is why I believe that it is crucial to solve issues (Student 13).*

These students described engineering as a collaborative and creative field that focuses on problem-solving. Teamwork and critical thinking are essential for transforming ideas into reality. Engineers generate innovative solutions, enhance existing systems, and create tangible outcomes. Engineering is viewed as a process of continuous improvement and applying creativity to practical challenges.

Discussion

This study's findings elucidate the diverse perceptions and definitions of engineering among high school students from various backgrounds. It highlights engineering's multifaceted nature, emphasizing its role as a problem-solving and innovative process. Key themes emerging from the students' responses include the integration of interdisciplinary knowledge, the significance of collaboration and creativity, and the recognition of engineering's role in addressing real-world challenges. These insights provide a valuable understanding of how students comprehend the multifaceted nature and importance of engineering in contemporary society.

A considerable number of students' descriptions of engineering emphasized its role in identifying and solving problems. Many students perceived engineering as a dynamic and iterative process involving critical thinking, creativity, and continuous improvement. This perspective aligns with the broader view of engineering as a discipline dedicated to finding and refining solutions to complex problems, often through trial and error [32-34]. Students underscored the significance of innovation and the potential for ongoing refinement, observing that engineering solutions are seldom static but rather evolve. This focus on innovation is in line with contemporary perspectives of engineering as a catalyst for technological advancement and enhancement of quality of life [35-37].

Furthermore, the students' understanding of engineering as an ongoing process of improvement and enhancement captures the dynamic nature of the field, where solutions develop and new challenges arise [38-41]. This insight highlights that engineering goes beyond merely resolving immediate issues, encompassing the vision and creation of better versions of existing systems, tools, and technologies. The idea of engineering as a driving force for improving efficiency and increasing accessibility has significant relevance in the practical applications of engineering across various industries, including healthcare, transportation, and information technology [42-44].

Another key theme identified was the interdisciplinary aspect of engineering, where students acknowledged the importance of knowledge from diverse areas such as science, mathematics, and technology. They consistently highlighted how applying existing knowledge leads to practical solutions, especially when integrating various branches of engineering like mechanical, software, and biomedical engineering. This reflects the extensive nature of engineering and its reliance on multiple academic disciplines [45-46]. One student aptly noted that engineering acts as an "umbrella term," encompassing various subfields, each employing distinct scientific principles and methods to tackle unique challenges.

The recognition that engineering involves integrating diverse knowledge areas also speaks to the increasing complexity of modern engineering challenges, which often require collaboration across various disciplines [47-48]. For example, advancements in fields like biomechanical engineering or software engineering require not only technical expertise but also an understanding of biological systems, social contexts, or computational algorithms [44, 49]. This interdisciplinary approach is crucial in addressing complex, multifaceted problems, which are increasingly prevalent in fields like sustainability, healthcare, and digital technology [49].

In addition, the perspective of engineering as both a discipline and a skill set highlights the field's practical applications. This discipline entails a strong foundation in scientific and technical knowledge, yet it also encompasses skills that enable individuals to innovate and develop real-world solutions. This dual aspect emphasizes the necessity for aspiring engineers to cultivate both theoretical knowledge and practical skills [5-53].

Lastly, another major theme that emerged from the students' descriptions was the significance of collaboration and creativity in engineering. Many students emphasized that engineering is not a solitary pursuit; rather, it is a collaborative endeavor that often requires teamwork to turn ideas into practical solutions. This is in line with modern engineering practices, where interdisciplinary teams join forces to address complex problems [54-55].The ability to communicate and work effectively with others is essential, as engineering projects typically involve various stakeholders, including designers, technicians, project managers, and clients [53, 56].

Additionally, students described engineering as a fundamentally creative discipline. They emphasized the importance of imagination and design in generating innovative solutions that address societal needs. This creative aspect of engineering was highlighted by students who viewed it as a process of constant iteration where improving existing ideas and systems is as integral to engineering as the initial problem-solving phase. The focus on creativity underscores a more human-centered aspect of engineering, where solutions are designed not only to be efficient but also to enhance user experience, accessibility, and overall quality of life [44]. The acknowledgment that engineering encompasses both technical expertise and creative thinking is in line with the increasing emphasis in engineering education and practice to nurture "design thinking" and "creative problem-solving" skills alongside traditional technical [57]. Engineering is not solely about applying formulas and calculations; it also involves envisioning new possibilities and translating abstract ideas into tangible solutions that address real-world needs.

Conclusion and Implication

In conclusion, the findings of this study offer a contextualized view of how high school students in this study perceive engineering. Within the scope of this research, participants tended to describe engineering as a creative, problem-solving, and interdisciplinary field, emphasizing the importance of applying knowledge across disciplines, collaborating effectively, and engaging in innovative thinking to address real-world problems. These insights emphasize the necessity for engineering education to cultivate an environment that promotes creativity, teamwork, and continuous improvement while also equipping students with the technical knowledge required to address the complex challenges of the 21st century. By aligning educational practices with these perceptions, educators can assist students in developing the skills and mindsets essential to thrive in an ever evolving and increasingly complex world field.

This research is novel in its focus on exploring students' descriptions of engineering associated with engineering in informal learning. It underscores the need for providing concrete experiences and examples to support engineering, as this can effectively integrate engineering into the educational curriculum and enhance students' understanding of engineering and engineers. The students' perceptions of engineering provide significant insights for shaping future engineering curricula. Since many students see engineering as a creative, interdisciplinary, and collaborative field, it may be advantageous for educators to emphasize these aspects in the classroom. Promoting teamwork, creativity, and problem-solving across disciplines could better prepare students for the challenges they will encounter in their careers. Integrating hands-on projects that combine technical skills with design thinking and interdisciplinary collaboration may also improve students' understanding of the real-world applications of engineering.

Furthermore, students' emphasis on the application of knowledge and the importance of innovation suggests that engineering education should continue to stress the value of practical, real-world problem-solving. Opportunities for students to engage with industry partners, work on live projects, and participate in research that addresses global challenges could further enrich their learning experiences.

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