Exploring Project Context in First-Year Engineering: Impact of Self-Directed Societal vs. Structured Technical Design Projects on Student Perceptions of Engineering

Dr. Muhammad Asghar, University of Cincinnati

Muhammad Asghar is an Assistant Professor in the Department of Engineering and Computer Education at University of Cincinnati (UC). Before coming to UC, he earned a Ph.D. in Engineering Education, a master's degree in clinical psychology, a master's degree in educational psychology, and a bachelor's degree in computer information systems engineering. Muhammad's research interests currently focus on students' mental health and well-being in engineering education. He is actively involved in research related to the use of Physiology Measurement Instruments to understand the behavior of engineering undergraduates.

Dr. Gregory Warren Bucks, University of Cincinnati

Gregory Bucks joined the Department of Engineering Education at the University of Cincinnati in 2012. He received his BSEE from the Pennsylvania State University in 2004, his MSECE from Purdue University in 2006, and his PhD in Engineering Education in 2010, also from Purdue University. His research interests lie in first-year pedagogy and program assessment as well as conceptual understanding of fundamental computing concepts.

Prof. Teri J Murphy, University of Cincinnati

Dr. Murphy is a professor in the Department of Engineering & Computing Education at the University of Cincinnati.

Jeremy Michael Olivar Hill, University of Cincinnati

Program Manager, Undergraduate Programs, Dept of Engineering & Computing Education

Dr. Cedrick Kwuimy, University of Cincinnati

Cedrick A. K. Kwuimy, PhD, is an Associate Professor–Educator in the Department of Engineering and Computing Education at the University of Cincinnati. His work examines how experiential learning becomes transformative and how such transformation expands students' capabilities and agency across formal and informal engineering education contexts. A Fulbright Scholar and Carnegie African Diaspora Fellowship Program Fellow, Dr. Kwuimy has designed and led capacity-building workshops on engineering formation in both Africa and the United States.

Exploring Project Context in First-Year Engineering: Impact of Self-Directed Societal vs. Structured Technical Design Projects on Student Perceptions of Engineering

Abstract

In this research paper, we examine changes in first-year engineering students' perceptions regarding: (1) their worldview, (2) the societal impact of engineering, (3) their engineering identity, and (4) their intent to persist in engineering, following their participation in a self-directed societal-context design project (Fall 2024) and then a structured technical project (Spring 2025) during a first-year engineering design course sequence. In the self-directed project, students were provided with an open-ended prompt which required them to both identify a population and the problem they wished to address for that population. In the structured project, the customer and the problem the students were required to solve was more clearly defined. While the students were still required during the second project to gather additional information to better understand the problem being addressed, more emphasis was placed on the development of the technical solution than understanding the context of the problem. These two courses (in the design course sequence) were designed and delivered using a Project-based learning (PBL) approach. PBL has been shown to enhance students' cultural awareness and broaden their understanding of engineering beyond purely technical dimensions. Further, PBL also helps shape students' perception of themselves as engineers and motivates them to persist in their engineering education. For this qualitative study, a random sample of 50 responses, 25 each from Fall and Spring semesters in a large Midwestern University in the US, were analyzed. Data were collected twice from the same population of approximately 1,300 students, in the form of end-of-semester graded reflections responding to four open-ended questions about changes in their perceptions across the four broader areas mentioned previously. Qualitative thematic analysis involving inductive and deductive coding, categorization, recategorization, and theming were conducted to identify patterns and insights in students' reflections, capturing changes in their perceptions of worldview, the societal impact of engineering, engineering identity, and intent to persist in engineering. A large language model (LLM), GPT-OSS-20B, was used on a local server as a second coder, achieving 85% intercoder reliability with the researcher coder. Findings suggest that both types of projects helped study participants understand 1) how engineering practice can potentially help solve real world solutions 2) the importance of social responsibility, and 3) the importance of collaborative teamwork. The societal-context design project helped improve participant persistence in engineering education while the structure technical project helped improve engineering identity. We expect the findings from this research to not only inform us about the impacts of different contexts of PBL but also support improvements in first-year engineering design curriculum according to the necessary needs and expectations of students.

Keywords: first-year engineering, project based learning, design process, design projects, transformative learning

1 | BACKGROUND

Since the turn of the century, engineering education worldwide is increasingly turning to project-based learning (PBL) to cultivate not only technical competence but also broader forms of social awareness and professional preparation [1, 2]. Unlike traditional lecture-based approaches, PBL situates learning within authentic, collaborative problem contexts, requiring students to engage with real-world constraints, stakeholders, and societal considerations. Prior research has demonstrated that such experiences can enhance students' cultural awareness by encouraging reflection on diverse perspectives and contexts [3], deepen their understanding of sustainability as an integral component of engineering practice [4], and support the development of engineering identity through sustained teamwork and project ownership [5]. Collectively, these studies suggest that PBL provides a pedagogical structure through which engineering students can develop socially informed ways of thinking alongside disciplinary knowledge.

This shift toward PBL is supported by a growing body of empirical evidence demonstrating its positive impact on student learning and professional development [1]. Studies employing diverse methodological approaches including quantitative assessments of technical and problem-solving skills, qualitative analyses of team interactions, and survey-based measures of professional readiness have consistently reported improvements in student outcomes within engineering contexts [6, 7]. Specifically, research has identified positive associations between engagement in PBL and enhanced problem-solving abilities [8], increased attention to ethical and societal considerations in engineering design [4], and improved communication and collaboration skills within diverse teams [5]. Furthermore, ongoing research has begun to examine critical design features of PBL implementations such as the degree of instructional scaffolding and the authenticity of real-world problem contexts to better understand how these elements influence learning outcomes and the development of socially responsible and professionally competent engineers [9, 10].

1.1 | Purpose

As part of a larger project [11-16], this qualitative study investigates how two sequential project-based learning (PBL) experiences: (1) a self-directed societal-context design project in Fall 2024 and (2) a structured technical project in Spring 2025 shape first-year engineering students' perceptions in four key areas: (1) their worldview, (2) the societal impact of engineering, (3) their engineering identity, and (4) their intent to persist in engineering.

To further understand the impact of project-based learning, we used the Transformative Learning Theory (TLT) as our theoretical framework. Utilizing TLT [17, 18], we argue that the degree of freedom students have within a project particularly regarding the problem context significantly shapes their worldviews, their perceptions of engineering's role in society, and the development of their professional identities.

2 | THEORITICAL FOUNDATIONS

This study is grounded in Transformative Learning Theory (TLT) for examining how first-year engineering students make meaning from design experiences and how project context shapes the depth of that meaning-making [17, 18]. Together, these frameworks support analysis of not only what students learn, but how and why their perceptions of engineering, society, and oneself evolve across differently structured design projects.

2.1 | The Mezirow's Transformative Learning Theory

Transformative Learning Theory (TLT) provides a framework for understanding how learners make meaning from experience through critical reflection on the assumptions that shape their interpretations [19]. Central to TLT is the idea that learning involves more than acquiring knowledge or skills; it entails examining how experiences are understood, evaluated, and integrated into existing frames of reference [17, 18]. Reflection plays a key role in this process and varies in depth, ranging from descriptive accounts of experience to critical examination of the beliefs, values, and expectations that guide perception and action [20, 21]. Critical reflection, particularly at the level of questioning underlying assumptions, is therefore essential for understanding when learning moves beyond surface awareness toward deeper changes in meaning-making [20, 22]. In this study, TLT is used to frame analysis of students' reflective responses by focusing on the depth of reflection evident in their writing, rather than assuming or asserting the occurrence of transformation.

2.2 | Transformative Learning Theory and Depth of Reflection

Transformative Learning Theory conceptualizes learning as a developmental process through which individuals critically examine and revise the assumptions that shape how they interpret experience [18]. Within this framework, reflection varies in depth and developmental consequence. Content reflection focuses on describing experiences or outcomes; process reflection examines strategies, actions, and learning mechanisms; and premise reflection entails questioning the assumptions, beliefs, or frames of reference that guide interpretation and decision-making [19, 23]. Premise reflection represents the deepest level of reflection and is a necessary condition for perspective transformation [18].

In first-year engineering contexts, reflection often remains at content or process levels, emphasizing task completion, technical correctness, or skill acquisition [24, 25]. Opportunities for premise-level reflection, where students interrogate assumptions about engineering knowledge, professional identity, societal responsibility, or personal purpose, are less common and typically under-designed [26].

3 | METHIODS

Qualitative data was collected from students participating in a self-directed societal-context design project (Fall 2024) and then a structured technical design project (Spring 2025) during a first-year engineering design course sequence at a larger Midwestern University in the US. Participant's completed end of semester reflections assignments while responding to four open ended prompts inquiring about: (1) their worldview, (2) the societal impact of engineering, (3) their engineering identity, and (4) their intent to persist in engineering. Following prompts were used on both occasions.

> **Prompt1:** Describe how completing the ENEDXXXX design project this semester has changed your view of the world.
>
> **Prompt2:** Describe how completing the ENEDXXXX design project this semester has changed your view of engineering/technology's role in society.

Prompt3: Describe how completing the ENEDXXXX design project this semester has changed your view of yourself as an engineer or applied scientist.

Prompt4: Describe how completing the ENEDXXXX design project this semester has changed (increased, decreased, no impact) your desire to pursue an engineering/applied science major.

3.1 | Participant Sampling

After approval from IRB, a third party was provided access to the student reflections assignment from around 1300 first year engineering students. They randomly selected 100 reflections, 50 each from fall and spring semesters from repeated students. They then de-identified these reflections and provided them to the research team. The research team selected 50 responses, 25 from each semester and from 25 repeated students based on the responses being more than just a line and potentially have substance that would be suitable for a qualitative analysis.

3.2 | Data Analysis

Thematic analysis of the de-identified open-ended responses to each of the four prompts was conducted [27]. An iterative, cyclical qualitative data analysis process involving coding, categorization, and theme development was employed. A combined inductive and deductive descriptive coding approach was used to further explore and elaborate on the elements contributing to first-year engineering students' perceptions of changes in their attitudes about their worldview, the societal impact of engineering, their engineering identity, and their intent to persist in engineering due to their participation in the semester long design project. A large language model (LLM), GPT-OSS-20B, was used on a local server as a second coder, achieving 85% intercoder reliability with the researcher coder. Local server was used compared to an LLM online model that would have been more powerful but might risk the the identity and confidentiality of the study participants. The prompt utilized with the LLM is provide in Appendix 1.

4 | FINDINGS

In this research paper, we examine changes in first-year engineering students' perceptions regarding: (1) their worldview, (2) the societal impact of engineering, (3) their engineering identity, and (4) their intent to persist in engineering, following their participation in a self-directed societal-context design project (Fall 2024) and then a structured technical project (Spring 2025) during a first-year engineering design course sequence. In the self-directed project, students were provided with an open-ended prompt which required them to both identify a population and the problem they wished to address for that population. In the structured project, the customer and the problem the students were required to solve was more clearly defined.

This findings section presents findings organized by reflection prompt to allow for a clear comparison of students' responses across two distinct design projects. First year engineering student participants answered the same four prompts in both the Fall (societal design project) and Spring (technical design project) semesters. By examining these responses, we identify shared themes alongside variations in how students interpreted the design challenges.

4. 1 | Prompt 1: Change in View of the World

a. Engineering practice helps understand professional realities (common theme)

Across both semesters, participants consistently viewed their design project experience as a valuable opportunity to gain insights into the realities of the professional world. This sense of immersion was particularly evident in their reflections on the project's relevance to future careers. For example, one participant wrote:

> "Completing the design project has given me a taste of how engineers in the real world get together and design products, whether they're assigned to do it or if they chose to. It showed me the common steps that every engineer takes in order to create a solution and how to implement it."

The study participants were keen to express their views about how the project taught concrete engineering methods and the importance of hands-on work to develop for future professions role in society.

b. Social responsibility and global awareness (common theme)

Another common theme was related to both, the societal, and technical projects helping study participants be more knowledgeable about the social responsibilities that engineers have towards the world. We noticed a shift from a purely technical mindset to a socially-ethical one, and the development of empathy for marginalized groups. Heightened awareness of worldwide disparities, resource scarcity, sustainability, and environmental problems that shape quality of life. This shift was elaborated by one of the study participants as:

> "I saw engineering largely as a technical field focused on creating solutions. However, through the project, I gained a deeper appreciation for how engineering decisions can have far-reaching social, economic, and environmental implications."

The above comment is a fine demonstration of how the design projects are capable of changing the perceptions of engineering undergraduate students and make them cognizant of not just their role in the society but also their responsibilities in the future engineering related careers.

c. Collaboration and human connections (common theme)

Study participants consistently described their experience as transformative, notably regarding their ability to collaborate effectively within teams and communicate professionally with diverse individuals. This focus on teamwork and communication was more prominent during the structured technical project (Spring 2025) compared to the societal-context design project. A study participant had the following to say about their project teamwork experience:

> "Before this project, I hated to work with large teams, especially if someone was not always committed. However, this project has shown me that the best ideas come from teams, as they can add valuable ideas about how to keep working and gives others time to take a break if they are burnt out of ideas."

This reflection underscores a key turning point – the participant's move from a negative, individualistic perspective to an appreciation for the benefits of collaborative design. It reveals a fundamental shift in how the participant conceptualized the design process, moving beyond the perceived limitations of working alone to embrace the potential for collective intelligence and innovative solutions that emerge from diverse viewpoints.

d. **Design thinking and innovation (structured technical project)**

Observed in the Spring 2025 responses, the study participants were of the view that the use of design-thinking, brainstorming, multiple solutions, and creativity helped them gain confidence in tackling complex problems creatively. The following comment demonstrates these types of views.

> "When our team was brainstorming how to design an arm that could actually pick up and weigh the container, I learned that problems don't have just one right answer. Every brainstorming session taught me to look at problems from multiple angles, think outside the box, and not be afraid to suggest different ideas. It opened my eyes to how much planning, trial and error, and persistence are needed to solve even "small" problems like lifting an object reliably."

It is interesting to note that the technical project was more structured compared to the Fall 2024 societal-context project yet the study participants found it to be more enriching when it came to using their creative muscles.

4. 2 | Prompt 2: Change in View of Engineering's Role in Society

Two complementing themes emerged in both Fall 2024 and Spring 2025 participant responses when they were reflecting on the role of engineering in society.

a. **Engineering Practice Can Potentially Help Solve Real World Solutions**
b. **Social Responsibility and Global Awareness**

Similar to the earlier prompt, again, there was a realization of the social responsibility that the engineering profession has towards society. In addition, they also reflected on the capacity of the profession to help elevate world problems and better human conditions through practical efforts. On of the study participants summed both of the themes in their reflection in the following.

> "I think I find engineering and technology's role in society much much more important because it is technology like the one we created which goes out to assist all the people affected by disasters and to alleviate the struggles of people all over the world. I think being a part of a community where we get to help people suffering from disastrous events is so rewarding and very important in society."

Both projects, irrespective of their nature, demonstrated a potential to bring about a shift in the study participants from a purely technical mindset to a socially-ethical one, and the development of empathy for groups that are under difficult circumstances and suffering.

4.3 | Prompt 3: Change in View of Yourself as An Engineer

a. Personal growth, enhanced self-perception of capability and increased engineering identity (common theme)

Though different in nature, both project experiences demonstrably helped improve the sense of engineering identity among the study participants. This wasn't simply a superficial shift in opinion; rather, the projects facilitated significant personal growth, enhanced self-perception of capability, and ultimately, increased engineering identity. Participants moved beyond viewing engineering solely as a collection of technical skills, gaining a deeper appreciation for the broader role of engineers in addressing complex societal challenges. One of the study participants described their gains with the following reflection.

> "I definitely can think of myself as more of an engineer after completing this project. This project has tested the limits of my design and critical thinking capabilities, as well as my ability to work as a member of a team. I have learned so much from this project in terms of what it feels like to create something that will help people and working through all the ups/downs and difficulties of the project, and creating a robot in itself makes me personally feel like I'm one more step closer to being able to call myself an engineer."

The participant expressed a strong sense of personal growth, explicitly stating that completing the project has enabled them to 'think of themselves as more of an engineer.' This was driven by the project's demands testing their design capabilities, critical thinking skills, and collaborative teamwork and the rewarding experience of creating a functional prototype, which they felt was a significant step toward achieving their goal of becoming an engineer.

b. Broadened engineering perspective beyond technical skills (societal-context project)

Study participants demonstrate a shift in understanding the role of an engineer, recognizing the importance of ethics, social impact, and critical thinking alongside technical knowledge. Since the project was by nature designed to enable students to research their populations and design products that might be capable of helping elevate the poverty levels of the selected populations, it was expected that students will be able to think beyond the technicalities of their engineering solutions. Such broadening of perspective was referred to by one of the study participants as follows.

> "Completing the design project has shifted my perception of myself from someone who only solves technical problems to someone who needs to think critically about the wider implications of solutions. I have come to understand that being an engineer requires more than just technical know-how."

Driven by the project's core purpose of investigating poverty alleviation and designing innovative solutions, participants moved beyond purely technical considerations, embracing a broader perspective that acknowledged the critical role engineers play in addressing complex societal challenges.

e. Practical application of engineering and creativity (structured technical project)

Study participants highlighted the importance of hands-on experience, problem-solving skills, and the realization of what engineering actually entails. Though there were references to the societal applications of the engineering applications, the focus was on the deliverables themselves and the nature of the design thinking process that led to these deliverables. This could well be because of structured nature of the project. One of the study participant reflected on this as follows.

> "I discovered how much I love the process of bringing an idea to life, seeing something that once only existed in my head come together physically, coded, moving, and working right there on the table. That feeling was incredibly rewarding. Engineering has always been a passion of mine, but this project deepened that love even more."

This deeply personal connection to the tangible outcome of their efforts undoubtedly solidified the participants' understanding and appreciation for the core values and rewards of a career in engineering.

4.4 | Prompt 4: Change in desire to pursue an engineering/applied science major

Most students reported an increase in desire to pursue engineering major as a result of the design projects. A small number reported their desire not to have been impacted by the project. For both types of projects, an acknowledgement of an engineering process-oriented value was the common theme and the main reason for an increase in the desire to pursue an engineering major.

a. Engineering process-oriented value (common theme)

The study participants reported that 'process-oriented value' the appreciation students place in the activities and practices of engineering and not just the end product/solution– as a source of encouragement towards an engineering major. Though, in the structured technical project, participants focused more on the design projects being a source of practical hands-on experience while in the societal-context project, participants also reported a sense of enjoyment and feeling accomplishment while engaging in the design process. The process orientation created a powerful sense of connection, leading participants to see themselves as participating in and succeeding within the practices of engineers, thereby fueling their interest in pursuing an engineering major.

5 | DISCUSSION AND CONCLUSIONS

Findings from this study align with a growing body of research demonstrating the crucial role of project based learning (PBL) in shaping students' perceptions of engineering education and future profession. Our finding that design projects, as an authentic form of engineering practice, helped participants develop an understanding of real-world engineering careers aligns with and is reinforced by [28], who reported that product design projects enhance engineering students' career prospects. Similarly, we found that projects based on supporting populations in need around the world increase a sense of social responsibility and global awareness in the project participants. Such findings have been previously reported by other researchers who state that project based learning help flourish students' cultural awareness [3] and enhances their understanding of the needs of sustainable engineering practices [4].

Though study participants in both projects viewed teamwork and collaborations to be an integral part of their project work that helped them change their world view about achieving goals towards being a part of a team than mere individuals, the feeling was more prevalent in the structure technical project rather than the societal-context project. We also found that the structured project was viewed as more enriching when it came to using creative muscles. We could not find definite literature that would help us understand why such teaming phenomenon might exist but there is research that emphasizes that the type of project environment plays a role in project team dynamics [29].

Similar to our findings, other researchers have also reported project-based experiences to be a contributing factor to student's engineering identity development [5]. In the same lines, we noted that personal growth and a feeling of an increased capability in engineering education through the design project provided a positive sense of being an engineer. Research reveals that project-based engineering courses effectively nurture students' self-efficacy, motivation, and perceived skill development, fostering a cycle of personal growth and increased confidence in their engineering abilities [30].

Lastly our study participants reported their project based experiences to be beyond mere technical skill acquisition opportunities. PBL is widely reported to broaden students' engineering perspectives beyond purely technical skills. For example, research has shown that students learn to integrate technical problem-solving with considerations of users, stakeholders, ethics, sustainability, and societal impact [31] and recognize engineering to be an iterative, collaborative, and value-laden, rather than linear and purely technical [32].

ACKNOWLEDGMENT

This work was made possible by a grant from the National Science Foundation (NSF # 2337003). Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

1. M. Prince, “Does active learning work? A review of the research,” *J. Eng. Educ.*, vol. 93, no. 3, pp. 223–231, Jul. 2004, doi: 10.1002/j.2168-9830.2004.tb00809.x.
2. S. Bell, “Project-based learning for the 21st century: Skills for the future,” *The Clearing House*, vol. 83, no. 2, pp. 39–43, 2010, doi: 10.1080/00098650903505415.
3. M. Akharraz, “The impact of project-based learning on students’ cultural awareness,” *Int. J. Lang. Lit. Stud.*, vol. 3, no. 2, pp. 54–80, 2021.
4. M. Jollands and R. Parthasarathy, “Developing engineering students’ understanding of sustainability using project based learning,” *Sustainability*, vol. 5, no. 12, pp. 5052–5066, Dec. 2013, doi: 10.3390/su5125052.
5. J. Chen, A. Kolmos, and X. Du, “An exploration of students’ engineering identity development in a PBL team setting,” in *Proc. 2020 ASEE Virtual Annu. Conf.*, Virtual Conference, Jun. 2020.
6. J. E. Mills and D. F. Treagust, “Engineering education—Is problem-based or project-based learning the answer?” *Australas. J. Eng. Educ.*, vol. 3, no. 2, pp. 2–16, 2003.
7. C. E. Hmelo-Silver, “Problem-based learning: What and how do students learn?” *Educ. Psychol. Rev.*, vol. 16, no. 3, pp. 235–266, Sep. 2004, doi: 10.1023/B:EDPR.0000034022.16470.f3.
8. A. Kolmos, E. de Graaff, and X. Du, *Research on PBL practice in engineering education*. Rotterdam, The Netherlands: Sense Publishers, 2009.
9. M. Prince and R. Felder, “Inductive teaching and learning methods: Definitions, comparisons, and research bases,” *J. Eng. Educ.*, vol. 95, no. 2, pp. 123–138, Apr. 2006, doi: 10.1002/j.2168-9830.2006.tb00884.x.
10. J. Strobel and A. van Barneveld, “When is PBL more effective? A meta-synthesis of meta-analyses comparing PBL to conventional classrooms,” *Interdiscip. J. Problem-Based Learn.*, vol. 3, no. 1, pp. 44–58, 2009, doi: 10.7771/1541-5015.1046.
11. “NSF Award Search: Award # 2337003 - Expanding Pathways for Preparing the Next Generation of Engineers: First-Year Engineering 2.0 (FYE2.0),” *Nsf.gov*, 2024. Available: https://www.nsf.gov/awardsearch/showAward?AWD_ID=2337003&HistoricalAwards=false. [Accessed: Mar. 16, 2025]
12. J. Kastner, G. W. Bucks, J. M. O. Hill, M. Asghar, T. J. Murphy, D. Reeping, and S. A. Sorby, "FYE 2.0: Re-envisioning the First-Year Engineering Curriculum," in *Proceedings of the ASEE Annual Conference & Exposition*, Montreal, Canada, 2025.
13. S. A. Sorby, M. Asghar, G. W. Bucks, J. M. O. Hill, J. Kastner, T. J. Murphy, and D. Reeping, "A Re-imagined First-Year Engineering Program—FYE2.0," in *Proceedings of the ASEE Annual Conference & Exposition*, Montreal, Canada, 2025.
14. W. S. Yeo, M. Asghar, and S. A. Sorby, "Characterization of Stress, Sense of Belonging, and Engineering Identity in First-Year Engineering Students," in *2024 ASEE Annual Conference & Exposition*, Portland, OR, USA, Jun. 2024.
15. Asghar, M., Reeping, D., & Sorby, S. (2025, November). Examining Shifts in Sense of Belonging, Engineering Identity, Intent to Persist and Stress Levels: A Repeated

Measures Study of First-Generation Students in a First-Year Engineering Program. In *2025 IEEE Frontiers in Education Conference (FIE)* (pp. 1-5). IEEE.
16. Asghar, M., Reeping, D., Bucks, G. W., Kastner, J., Murphy, T. J., & Sorby, S. A. (2025, June). Analyzing Self-Reported Sense of Belonging, Engineering Identity, Intent to Persist, and Stress Levels Among First-Generation and Non-Traditional Students in a First-Year Engineering Program. In *2025 ASEE Annual Conference & Exposition*.
17. J. Mezirow, *Fostering critical reflection in adulthood: A guide to transformative and emancipatory learning*. San Francisco, CA: Jossey-Bass, 1990.
18. J. Mezirow, *Learning as transformation: Critical perspectives on a theory in progress*. San Francisco, CA: Jossey-Bass, 2000.
19. J. Mezirow, *Transformative dimensions of adult learning*. San Francisco, CA: Jossey-Bass, 1991.
20. J. Mezirow, “Transformative learning: Theory to practice,” *New Dir. Adult Contin. Educ.*, no. 74, pp. 5–12, 1997, doi: 10.1002/ace.7401.
21. S. D. Brookfield, *Becoming a critically reflective teacher*. San Francisco, CA: Jossey-Bass, 1997.
22. P. Cranton, *Understanding and promoting transformative learning*, 2nd ed. San Francisco, CA: Jossey-Bass, 2006.
23. C. J. Finelli, M. A. Holsapple, E. Ra, R. M. Bielby, B. A. Burt, D. D. Carpenter, T. S. Harding, and J. A. Sutkus, “An assessment of engineering students’ curricular and co-curricular experiences and their ethical development,” *J. Eng. Educ.*, vol. 101, no. 2, pp. 359–379, Apr. 2012, doi: 10.1002/j.2168-9830.2012.tb00059.x.
24. A. Kitchenham, “The evolution of John Mezirow’s transformative learning theory,” *J. Transform. Educ.*, vol. 6, no. 2, pp. 104–123, Apr. 2008, doi: 10.1177/1541344608322678.
25. S. D. Sheppard, K. Macatangay, A. Colby, and W. M. Sullivan, *Educating engineers: Designing for the future of the field*. San Francisco, CA: Jossey-Bass, 2009.
26. J. Turns, B. Sattler, K. Yasuhara, J. Borgford-Parnell, and C. J. Atman, “Integrating reflection into engineering education,” *J. Eng. Educ.*, vol. 103, no. 3, pp. 398–423, Jul. 2014, doi: 10.1002/jee.20054.
27. J. Saldaña, *The coding manual for qualitative researchers*. Los Angeles, CA: SAGE, 2021.
28. U. Burnik and A. Košir, “Industrial product design project: building up engineering students’ career prospects,” *Journal of Engineering Design*, vol. 28, no. 7–9, pp. 549–567, 2017, doi: 10.1080/09544828.2017.1351152.
29. J. Goñi, C. Cortázar, D. Alvares, U. Donoso, and C. Miranda, “Is teamwork different online versus face-to-face? A case in engineering education,” *Sustainability*, vol. 12, no. 24, p. 10444, 2020, doi: 10.3390/su122410444.
30. L. L. Wu, C. Fischer, F. Rodriguez, G. N. Washington, and M. Warschauer, “Project-based engineering learning in college: associations with self-efficacy, effort regulation, interest, skills, and performance,” *SN Social Sciences*, vol. 1, no. 12, p. 287, 2021, doi: 10.1007/s43545-021-00286-4.

31. D. H. Jonassen, J. Strobel, and C. B. Lee, “Everyday problem solving in engineering: Lessons for engineering educators,” *Journal of Engineering Education*, vol. 95, no. 2, pp. 139–151, Apr. 2006, doi: 10.1002/j.2168-9830.2006.tb00885.x.
32. J. Turns, B. Sattler, K. Yasuhara, J. L. Borgford-Parnell, and C. J. Atman, “Integrating reflection into engineering education,” *Journal of Engineering Education*, vol. 103, no. 3, pp. 397–431, Jul. 2014, doi: 10.1002/jee.20051.

APPENDICES

Appendix 1

Prompt used on Large Language Model gpt-oss-20b on a local server

First year engineering students responded to the following open-ended prompt:

- Four prompts, as can be seen in the methods section of this paper, were provided here one by one.

Qualitative data collected was collected in response to the above prompt. Following are 25 excerpts from 25 students in response to the above open-ended prompt. Each paragraph represents a student response:

- 25 excerpts were provided here

You are a qualitative researcher. Based on the above question and the following 25 excerpts in above, code the data according to the following provided codes:

- Codes developed by the researcher were provided here.