

WIP: Perceptions of Agency in an Introductory Engineering Design Experience

Jutshi Agarwal
Department of Engineering Education
University at Buffalo, SUNY
Buffalo, NY, USA
jutshiag@buffalo.edu

Corey Schimpf
Department of Engineering Education
University at Buffalo, SUNY
Buffalo, NY, USA
schimpf2@buffalo.edu

David Evenhouse
Department of Engineering & Computing
Education
University of Cincinnati
Cincinnati, OH, USA
evenhodd@ucmail.uc.edu

Abstract—This work-in-progress research paper outlines an exploratory study that investigates the agency of engineering students in the context of design-based learning experiences. Professional engineers engage in various decision-making activities when tasked with the design of a product, system, or service. Such decisions are either informed by constraints placed by stakeholders or are a consequence of trade-offs between multiple criteria in the design process. In both scenarios, engineers have to exercise agency in how they approach information seeking, goal-setting, solution generation, prototyping and testing. This requires them to be comfortable both with being given agency, and in utilizing it to their advantage for effective problem-solving. Therefore, it is important to expose students to learning environments where they have opportunities to make choices and evaluate those choices in the context of problem solving. There is also literature to suggest that opportunities for exercising agency in educational contexts improve learning, engagement, and develop skills of critical thinking and innovative problem-solving. Such opportunities are created through learning activities with different levels of scaffolding, open-endedness, and course integration - from the use of open-ended modeling projects within specific content areas, to entire design courses that invite students to exercise agency at all steps of their design process. Though agency has been studied before in these contexts, there is a dearth of studies that examine how such opportunities to practice agency impact students during their engagement with engineering design. This study aims to begin addressing this gap by exploring the research question: *How do first-year students experience agency in an introductory design project?*

The study uses data from the first-year course sequence of an engineering program offered at large, Midwestern, public university. Students from all engineering disciplines enroll in this course and complete multiple design-related problems and projects in a team-based learning setting. This paper will present the initial results of an inductive analysis of 3 semi-structured interviews conducted with the students, capturing their own perceptions regarding their ability to make decisions throughout the project and examining the structures that encouraged or inhibited them in exercising agency. This research has implications for engineering instructors related to the design of learning environments that foster agency and the role that scaffolding plays in forming agentic student behaviors. Future work will expand our study of student perceptions of agency to include other mediating factors such as self-efficacy, motivation, and constraints on their learning experience.

Keywords— agency, design-based experience

I. INTRODUCTION

Engineers solve ill-defined open-ended problems in their profession. Capstone design courses are implemented in engineering education contexts to provide authentic experiences that imitate such workplace-like environments. But research has suggested that upper-level students experience difficulties in problem-definition, making assumptions, selecting appropriate problem-solving approach, and working in a system of systems context [1], [2]. Researchers and educators are thus implementing open-ended problems earlier in engineering programs to meet ABET requirements and to provide more opportunities for authentic experiences and preparing students during the transition into college [3], [4], [5]. Solving open-ended problems requires practicing agency – “the capacity to make choices and guide one’s actions towards a self-directed goal.” In a design process, engineers have to practice agency in prioritizing the needs of stakeholders to address, making tradeoffs between constraints and problem criteria, and selecting from a multitude of solutions [6].

Practicing agency in education contexts improves critical thinking, learner engagement, autonomy, self-regulation, metacognition, and academic performance [7], [8], [9], [10], [11], [12], [13], [14]. However, students need repeated exposure to agentic opportunities to become comfortable with its challenges. There is a significant dearth of literature on how engineering students respond to agency. Furthermore, we did not find a lot of studies on agency in engineering design contexts for first-year students. This paper aims to fill this gap by examining the perceptions of students in a first-year engineering design thinking course at a large, Midwestern, public university. The research question addressed in this study is: *How do first-year students experience agency in an introductory design project?* We present a preliminary analysis of 3 semi-structured interviews that resulted in themes of how students practiced agency differently.

The paper is structured into four remaining sections. The following section gives an outline of prior research in the area of agency. It is then followed by a description of the methods employed, the preliminary findings and a discussion outlining the implications, limitations, and future work associated with this study.

II. LITERATURE REVIEW

The study of agency originated in the social sciences and has been theorized by several scholars [15], [16], [17], [18]. A central theme in the theory of agency is that it is domain specific and thus can be defined specifically in the context where it is applied. In education, *learner agency*, “students’ will and capacity to act” [9], and *epistemic agency*, the opportunity to shape one’s own discipline-based knowledge-building [19], have noteworthy implications on how learning is shaped in classrooms. Scholars have further specified the term in more distinct contexts such as *framing agency* as the decision-making capacity in defining and bounding a problem in engineering capstone design courses [20], [21], [22], [23]. In this study, we operationalize agency as the freedom students experience in open-ended problem solving.

Another significant characteristic of agency is that it is multidimensional and is shaped by intrapersonal, behavioral, and environmental factors collectively [8]. Thus, individual predispositions, attitudes, and the broader context can lead to the same opportunity being perceived differently between students [10].

There is limited research on agency in engineering education contexts. When applied in project-based learning and collaborative learning contexts, motivation, self-efficacy, team behaviors, team dynamics, and course satisfaction significantly impact learner agency among engineering students [8]. Utility value, trust for teacher, and teacher support were also found to impact agency [14]. Implementing agentic opportunities in engineering through open-ended problems has been a challenge owing to the perception that students resist the discomfort experienced in such problems [24] and the lack of historical experiences among instructors in implementing such problems [25]. Research that points to students experiences and the nature of scaffolding that can improve learning in such contexts can help provide knowledge on structuring such problems. This study aims to add to knowledge in this area. In the next section we describe the methods used in this study.

III. METHODS

In this section the methods are presented using two sub-sections. The first outlines the setting of the study and a description of the open-ended problem used as an agentic opportunity to understand student experiences. The second sub-section outlines our data collection process including the semi-structured protocol development and analysis procedures.

A. Educational setting and design problem

The context for this study was an open-ended (see [3]), collaborative design project taking place in a Freshman (i.e.: First Year) introductory engineering course at a large, research-intensive university in the Midwest United States during Spring of 2024. The problem – which required students to create a digital sorting device that could count and distribute balls of varying size, color, and weight – was introduced in the 4th week of a 16-week semester. Teams of 4-5 students were asked to plan, develop, and prototype a well-documented physical solution to be demonstrated in week 15. Two intermediate deadlines were also included to ensure teams made progress

during the early parts of the semester (i.e.: before Spring Break in week 10).

Introductory materials provided extensive information regarding an exemplar real-world context for the project, design specifications, project constraints, and required deliverables. However, only the size, component parts (limited to a provided kit excepting a \$15.00 budget for external materials), target performance metrics, and input location for the sorting device were strictly defined. All other criteria were left intentionally broad, allowing teams the opportunity to ask their own clarifying questions and explore a variety of possible solutions.

The students themselves also constituted an important part of this study’s context. Spring was the “off-sequence” semester for the course in question, and the involved student population included a higher number of adult and non-traditional learners than is typical for the university. In an informal survey, approximately 1/3rd of students self-reported extracurricular responsibilities taking a large portion of their time each week, with about 1/8th of students reporting time constraints comparable to working a full time (or near-full time) job.

The course likewise included many students who did not pass or complete the course during their previous semester (for any number of academic or non-academic reasons). While large-scale design projects are consistently a part of this introductory course, we would like to note that the variation of the project used in Spring of 2024 was new and should not have been familiar to any of the student participants.

Content of the course included a variety of topics related to design and the design process, problem solving strategies, project and team management, data modeling and analysis (using computational tools), and a variety of other disciplinary or technical topics. While students were required to demonstrate their mastery and application of course content through their solution to the open-ended design problem, the choice of *which* topics they utilized, and the *manner* in which those topics were applied, was left up to the student’s discretion.

B. Data collection and analysis

Data was collected using semi-structured interviews. A protocol was developed that asked participants about their prior experience with open-ended problems and various aspects of agency including what enabled and constrained them in the practice of agency. Agency was operationalized as the freedom to make decisions, set goals, propose ideas, or take self-directed actions. The protocol was first piloted with two upper-level students from a different university and iteratively revised to align with the context of a first-year course.

Students were recruited by presenting the details of the study during a regular class period. A sign-up link was provided that asked for students’ availability for an interview and basic demographical information. Three students (Participant X – self-selected pseudonym, Gandalf – self-selected pseudonym, and Jaimie – researcher-assigned pseudonym) signed up and were interviewed over a video-conferencing platform. The interviews lasted approximately an hour, were recorded and transcribed. The first author inductively coded the three interviews two times to establish reliability. Codes across the

three interviews were selected as themes and are presented in the following sections.

IV. FINDINGS

In this section, we outline the themes that emerged from our inductive analysis of the interviews. We first present a brief discussion on how students perceived freedom in the project to support the context as an opportunity to practice agency. The next four sub-sections are a discussion of four different ways students practiced agency in this context respectively while the last sub-section describes the constraints they experienced in this process.

A. Perception of agency

In our review of the students' discussion of the design project, we observed instances where students perceived agency in the problem statement and its implementation in the course. Participant X reflects on their freedom: *"I mean, to be honest with you. It was throughout the entire project, we all felt pretty free to do whatever we wanted to do with it as long as it was, you know, moving the project forward."* And more specifically later, *"I guess it was just the freedom to think and then test it."* We refer to these instances as a way to ground the context of the study with evidence of agency.

B. Agency of goal-setting

A notable way students expressed agency was through setting their own goals, primarily as a team. While all three students mentioned grades as a motivator, students also had their own criteria for success of the project and what they wanted to accomplish. In Gandalf's team, a focus on working efficiently but with a low cognitive load was evident, *"this will save us the most work because we don't have to work on like putting into sensors and encoding it in and like, we were aiming to be as, like minimal, as efficient as we could."* While Participant X's team started with a conservative goal and then challenged themselves to go beyond the minimal requirements, *"we achieved, or we strived for bare minimum to start. But then once we hit bare minimum, it was like, we gotta make it better."* We did not find significant mention of the participants' individual goals, however.

C. Agency of task delegation

In conversations with the students, it was apparent that each team identified roles between members differently and thus practiced agency of task delegation. While Jaimie acted as the project manager in their team organizing work of a designer, builder, and coder collectively, Gandalf was the "unnamed leader", and Participant X's team did not have set identified roles and switched between tasks as needed.

D. Agency in using resources

Students utilized their freedom in relying on resources they had access to. Both Jaimie and Participant X took advantage of their personal network such as family and friends to help them navigate circumstances during the completion of the project. Gandalf mentioned using their coursework and prescribed

materials from the course while acknowledging that they had access to the teaching team that they didn't utilize as a resource.

E. Agency in selecting solutions

Owing to the open-ended nature of the problem, there were a large number of possible solutions. Students practiced agency in both how they approached the problem and what solutions they chose. Gandalf describes a system of systems approach, *"we had the freedom to, for example, decide between like using a mechanical sorter, and like using a balance or using the weighted sensor that was given to us as part of the Lego kit, and then deciding which of those, how the system would have to look to get to each of those. So, it was like our choice on what versions of everything we could have done that we wanted to create what we thought was the best version that you could have."* They go on to state that they had the freedom to express creativity in the project.

F. Constraints

The above discussion details different ways students practiced agency. This sub-section focusses on the constraints and challenges they experienced when faced with agentic opportunities. A common and intuitive theme that emerged out of student interviews was the limited number of physical resources (in terms of the Lego kits and its content) they had in building their prototype. Students also talked about the constraints in time as they got closer to the deliverable deadlines. However, Participant X acknowledges that the project was assigned early in the semester which they found helpful.

In our discussion so far, we have made references to the team-setting of the project, also evident in the use of "we" instead of "I" in student direct quotes. The general team dynamics was a significant factor and constrained the agency of two of the students. Both Gandalf and Jaimie expressed losing their voice in their teams. Jaimie's interactions with their team appeared most challenging as they were not able to take the desired role in the team and the completion of the project. They say, *"But there is still some kind sometimes we ended up scrapping an idea entirely because we just couldn't agree on how it should be done."* They disclosed losing motivation towards the project due to challenges in communication with their teammates.

When faced with challenges in the project, both in communication and applying their learning to navigate the problem statement, students conveyed experiencing disorienting dilemmas in their self-perception in the form of self-doubt. Jaimie mentioned doubting themselves when fulfilling the role of a project manager and having to manage team members who were older than them. Participant X mentions, *"At first, it was a bit of a confidence shaker, like, oh, man, like, I thought I could do any of this stuff."*

V. DISCUSSION

In this work-in-progress paper, we presented emerging themes on agency of engineering students in a design problem. We analyzed interviews with three students in an introductory

engineering and design thinking course. We presented a discussion of our findings related to the different ways students practice agency and the challenges they encounter in the process. Students expressed agency through their goal-setting, task delegation, resources they used, and the solutions they select. We also discuss challenges of team-setting projects and disruptions in self-perception.

Our work on agency in engineering originally started as an exploratory investigation of student experiences in open-ended modeling problems in a mechanics course where preliminary themes emerged [26]. In continuation of that work, we presented a model of how students navigate agency in the same course sequence [27]. In our analysis of the interviews in the current study, we explored the student experiences in a design project and found several instances that aligned with our model. Themes such as relying on prescribed, external resources, prior experience, and feedback from instructor were common across the studies. A discussion of how both groups of students perceived the open-endedness to be close to “real-world problems” has been omitted from this work-in-progress to avoid redundancy.

The emerging themes in this study point to a favorable response to implementing open-ended problems in introductory courses and suggests students exhibit agency in diverse ways. This has implications for engineering educators in fundamental engineering courses. Contrary to the perception that students resist open-ended problems [24], the participants in this study recognized the project as a learning opportunity. The challenges discussed in this study suggest that when such problems are administered in a collaborative setting, instructors may need to set up more scaffolding for teamwork including but not limited to getting feedback from students on their team dynamics throughout the semester. It may also be helpful to provide support with affirmative dialogue on how agentic opportunities pose challenges that need to be navigated for positive outcomes.

Our work on exploring agency in engineering is ongoing. We observed instances where students hinted at motivation, their previous experiences with open-ended problems, and the structure of the problem statement which influenced their practice of agency. Due to the small sample size, we were not able to generate conclusive themes on those issues which will be investigated in future studies. Next steps involve exploring experiences with agency in students in upper-level courses such as capstone courses and comparing experiences across levels. We also hope to find emerging themes that help us understand how constraints and structure of the problem are perceived differently student to student. Grounding the experiences in individual characteristics such as motivation, self-efficacy, and predispositions towards agentic decision-making can help connect the findings to prior work on the multidimensional nature of agency such as [8].

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