Exploring how Students Grapple with Agency in Open-Ended Engineering Problems

Dr. Corey T. Schimpf, University at Buffalo, SUNY

Corey Schimpf is an Assistant Professor in the Department of Engineering Education at the University at Buffalo, SUNY. His lab focuses on engineering design, advancing research methods, and technology innovations to support learning in complex domains. Major research strands include: (1) analyzing how expertise develops in engineering design across the continuum from novice pre-college students to practicing engineers, (2) advancing engineering design research by integrating new theoretical or analytical frameworks (e.g., from data science or complexity science) and (3) conducting design-based research to develop scaffolding tools for supporting the learning of complex skills like design. He is the Division Chair Elect for the Design in Engineering Education Division for the 2023 ASEE conference.

Esther Komolafe, University at Buffalo, SUNY

Esther Komolafe is an undergraduate Biomedical Engineering student at the University at Buffalo. Throughout her educational career she has applied herself to several different projects. She is currently working as a researcher for the Engineering Education Department at the University at Buffalo where she analyzes and qualitatively codes data. She has worked as a research assistant at an engineering lab on campus, where she conducted research on the molecular and cellular mechanisms of liver organogenesis. She has showcased her desire to positively impact the medical industry by volunteering at Flushing Medical Center in Queens, NY. Furthermore, she has served as a pharmacy technician where she supported pharmacological services and assisted patients. Esther is currently in her final year and is hoping to pursue her master's degree while establishing a career in the biomedical engineering field.

Dr. Jessica E. S. Swenson, University at Buffalo, SUNY

Jessica Swenson is an Assistant Professor at the University at Buffalo. She was awarded her doctorate and masters from Tufts University in mechanical engineering and STEM education respectively, and completed postdoctoral work at the University of Michigan. Her current research involves examining different types of homework problems in undergraduate engineering science courses, the intersection of affect and engineering identity, and improving the teaching of engineering courses.

WIP: Exploring how Students Grapple with Agency in Open-Ended Engineering Problems

Introduction

This work in progress paper examines student agency in engineering problem solving. Typical engineering homework problems, especially those assigned in engineering science courses, require the use of a particular set of equations, usually to build mathematical fluency and learn conceptual knowledge. These are usually referred to as "plug and chug" problems. Our research team, along with other professors from across the country, have created ill-defined problems assigned in statics and dynamics to counter this pattern of problem solving and engage students in making assumptions and determining the reasonableness of their answers [1], [2]. In short, we gave students agency to define and decide on how they wanted to go about their problem-solving process, hoping this would engage them more in conceptual knowledge building and sense-making. The purpose of the study is to gauge how students feel regarding freedom and agency over their work. We want to evaluate their responses to having more authority over the way they address, solve, and present their work. We would like to see how giving students more freedom to make decisions impacts their learning experience. Some work has begun to explore how students enact agency in open-ended engineering problems [3] or how students perceive agency in open-ended problems [4], [5]. However, given the complexity of the concept and the variety of ways agency may be encouraged there is a need to better understand how students respond to being given agency through inductively driven inquiry. Moreover, there are opportunities to leverage theoretical frameworks such as from science education where agency has been heavily researched [6]–[9] which have not been fully utilized in EER. To explore this topic, we ask: In what ways do students experience agency within the context of working on open-ended engineering problems?

In the remainder of the paper, we review the background on what agency is and some ways it has been theorized. Following this we present the study context for the OEMP project, as well as how data was collected and analyzed through thematic analysis. The results cover each of the agency-related themes we identified. In the discussion, we relate these back to key theories about agency, before concluding the paper.

Background

There has been a large amount of theorizing and research on agency within the field of science education [6]–[14] and this topic has received growing attention in EER [3], [4], [15]–[17]. Agency may be considered instances where people take self-driven actions, but these have to be reconciled with social structures (e.g., classroom norms and expectations) that constrain what actions can be taken [12]. In the social sciences there has been contention over the relative influence of structure and agency on human behavior [18]–[20], however several educational researchers argue for the importance of examining students' agency as a key component of learning and development, while acknowledging how social structure still shapes behavior to varying degrees [3], [10], [12].

While there are many ways in which agency has been conceived or extended into learning contexts, we focus on two key frameworks from science education that hold promise for studying engineering problem solving. First, we turn to epistemic agency, defined as : “students being positioned with, perceiving, and acting on, opportunities to shape the knowledge building work in their classroom community” [9], p. 1058. Moreover, epistemic agency is grounded in the disciplinary boundary’s students are working in, and the knowledge generation and practices of that discipline [8]. Second, Engle and Conant’s [6] work outlines four principles for creating projects that support students' productive disciplinary engagement (PDE). Two of these principles are closely related to agency: authority and accountability. Authority, in ways interchangeable with the general definition of agency above, refers to students having an active role in defining, addressing, and resolving disciplinary problems [6]. In contrast, accountability means students' work is responsive to knowledge and practices of those with a stake in the disciplinary area in which they are working, both inside and outside the classroom [6]. Authority and accountability as principles built into open-ended learning contexts need to be balanced appropriately or risk creating projects that are either over or under structured [7].

Epistemic agency’s focus on students' disciplinary context and Engle and Conant’s principles for creating and constraining agency opportunities make these frameworks potentially fruitful for examining students' perceptions of agency in engineering problem solving. These theories are contextualized in the results; we did not analyze our data deductively for these theories.

Research Design and Methods

Four participants completed two Open-Ended Modeling Problems (OEMP) projects as part of their first year statics course at a small private university in the southern United States [1], [2], [21], [22]. The first was a car crash at an intersection on campus. The second was a student-selected system. To complete the problems, students needed to make a number of assumptions about dimensions, simplifications, and applied forces to create a free-body diagram of either the car crash or their selected system. They then used equations taught to them in class to create a mathematical model and present and discuss their analysis of the scenario. OEMPs have multiple potential solutions and require students to make assumptions and judge the reasonableness of their solution. Students who were enrolled in the Dynamics course were asked to participate in an Institutional Review Board (IRB) approved study. Students who consented to participate in interviews were randomly selected to participate and contacted by e-mail to set up a date and time. During the consent process, students were also asked to select a pseudonym to best represent themselves. All interviews took place and were recorded on Zoom. In the interview. students were asked to recall how they solved the OEMP (in this case two) and were prompted to provide more details if their description was sparse. Students were then asked to evaluate their model, provide their thoughts on the OEMP problem, and finally answer some demographic questions. Critically, students were not directly asked about agency or related themes. Prior analysis had indicated this was a recurring theme in several of the ways students discussed how these problems felt or were different from other problems they were assigned in their engineering courses. In other prior analysis, we noticed the word “freedom” was used quite frequently and made us curious to further explore this topic.

Author 2 analyzed the data, through thematic analysis. Thematic analysis involves analyzing qualitative data, in this case interview transcripts, and identifying common themes or patterns across participants'

experiences [23]. The first step was to have an idea what exactly to look for. The main concepts we were trying to expand upon were freedom and agency. It is important to note that this work was exploratory and inductive, we were not analyzing utterances deductively to identify aspects of epistemic agency [8] or Engle and Conant's authority/accountability [6]. Instead, we use our results to start to contextualize these theories into EER. Author 2 read through the transcripts and highlighted anything they deemed as relevant. When they came across responses they were unsure about they highlighted these for later discussion. After the first read, they would go over the transcript. Usually after reading the transcript again, the Author will come across utterances that they may have initially missed, and they also have the opportunity to review previous highlights. Once the findings were highlighted, the Author wrote a short comment labeling it. For example, this utterance: "We basically just used as a calculator. It wasn't writing a MATLAB script. I know some groups did that and those looked really complicated. I know ours is just, that way we could work on it together and didn't get really mixed up and messy. We just use sheets…" was coded as selecting tools, a theme discussed below.

After labeling, Author 2 met with the other authors to discuss and analyze the codes together. Codes were further developed or adapted as needed from these discussions. After analyzing several transcripts, Author 2 wrote a memo [24] summarizing the main ideas and themes. This helped the author to condense their findings into one document and made it easier to review their work. Author 2 then worked with the other authors to finalize the set of themes and resolve any disagreements.

Results

Table 1 displays the number of utterances found for each of the six themes related to agency, by participant.

Table 1
Themes by Participants

	Prescribed Agency	Challenges of OE problems	Agency Outcome	Prob Set & Real-World Comparisons	Outside Resources	Selecting Tools
Cristina	6		3	2	1	1
Lane Marigold	3		3		1	
007	1	1	1	2		1
Joe Wong	1	1		3		1

Prescribed agency involves instances where students described taking some self-driven action but where this action was at least partially informed by, asked for, or influenced by their OEMP assignment. For example, while describing their experience with the car crash OEMP Lane Marigold describes their decision making behind modeling a car bumper "I'm not sure if this is a bumper that was used in actual production, but there was a bunch of different versions of just ideas of bumpers with the two spring

method and I liked the way that that worked with the math, so I went ahead and used it." While the student is making decisions on what specific bumper to model and factors in their preferences for how it operates mathematically, students were asked in the OEMP to model a bumper. Therefore, although students exhibit some agency for these codes, the general direction of this activity was encouraged explicitly by the assignment.

Challenge of open-ended problems refers to limitations or difficulties related to open ended problems and how these may affect the student's learning experience. In the 007 interview, the student says " …[W]ith open ended problems. It's hard to know exactly what reality answers are…How, how accurate this is or to reality." Because open ended problems leave room for interpretation and different ways to approach the problem, students may find it difficult to address or reach a solution. Unlike problem sets, the OEMPs do not have one specific answer.

Agency outcome is characterized by the potential outcomes that may come from students experiencing agency. These include, but are not limited to, increased confidence, enjoyment, and better application of skills. A common experience shared by several students is more enjoyment while working on the project. Cristina expresses, "It makes me feel like we get to apply what we've learned more… I just feel like I get more satisfaction out of doing these problems. It just makes me feel like I can apply what I've learned in realistic scenarios… So I just felt like I like it better because you get to apply things. You get more out of it in general."

Problem set and real-world comparisons refer to utterances where the student compares their experience with both types of assignments in comparison to OEMPs. A common observation made by students was how the freedom that comes with OEMPs gives a more realistic approach to engineering and prepares students for the real world. For 007 they express how doing endless problem sets gets "tiring." Joe Wong says "We have a lot more freedom when we're solving this problem. And I think that is pretty large because that would be the closest to the real world is no one's going to tell you." Most of the students share the sentiment that OEMPs enable students to utilize their skills in a realistic manner and prefer these problem sets.

One of the ways in which students chose to apply agency within the assignment was by bringing in outside resources. Several students conducted additional research and reviewed other sources in order to execute the assignment better. When explaining how they came up with their answer, Lane Marigold says "And so I believe that the amount of calculations that I did and the amount of research that I did really made this the best result that I could come up with for a final answer." Cristina talks about how they modeled their problem and says "I tried using realistic things, things that were found in the real world, taking ideas from other research. Just looking at them. I looked up things and looked at my options." Rather than relying on the resources they were initially given, students displayed agency by taking the initiative to conduct further research and bring in outside resources to help them achieve their objectives.

Another way students took agency over their work was through selecting tools. Although the problem is open-ended, there are a few recommendations made by the professor. However, some students took advantage of the freedom they had and selected tools that met their own needs and criteria. One example of this is seen in Lane Marigold. The students explain how MATLAB was recommended for solving a

part of the problem. However, they weren't too familiar with that sort of programming, so they opted for a more traditional way of solving problems. "Dr. Weir talked about using MATLAB or some other program to help you solve it. I wanted to do the work myself to kind of see if it worked out each time and I was a little hesitant on the process that I had already taken. I didn't want to go through programming MATLAB and then having mistakes and then trying to figure it out. So, I just plugged and chugged essentially to get all my answers on my own. For stuff like that, I just like to do it the same every time to ensure that I at least keep the process the same." The student chose a tool that they were more confident in and made the appropriate decision for their situation.

Discussion and Conclusions

While space constraints and the exploratory nature of this work prevent us from fully comparing the results to the agency theories covered, we can start to see some theoretical support and potential ways to adapt these theories into EER. Prescribed agency relates to giving students some authority and the utterances indicate it can be encouraged through curricular design or scaffolding [25], [26], as Engle and Conant [6] argue in their PDE framework. This also raises questions about when or how agency should be more or less "prescribed." Selecting analytical tools to use and engaging in research demonstrates more student-driven authority compared to prescribed agency. Additionally tool selection and research represent key practices in engineering, suggesting students were undertaking some epistemic agency, as this is a discipline-based form of agency [8]. Gainsburg's [27] analysis of structural engineers' mathematical practices also identified choices about tools as a key disciplinary practice. Moreover, past research that explored how students engaged with engineering textbook problems also uncovered that students use several kinds of outside resources [28]. For problem set and real-world comparisons students emphasized how OEMP's provided a more authentic and professionally relevant means for engaging in engineering problem solving. In short, students recognized they had greater epistemic agency to contribute to or shape the knowledge and practices in engineering as a disciplinary field. Challenges of open-ended problems seems to relate to Engle's [7] discussion about balancing authority and accountability in PDE and may indicate some students felt OEMP's gave them too much authority, compared to what they were familiar with. Finally, agency outcomes do not clearly relate to either of the theories.

This work-in-progress study begins to explore how students experience and respond to being given more agency in their work. We identified several ways in which students utilized or responded to agency within the context of OEMPs and saw preliminary evidence that students' experiences relate to theories of agency including epistemic agency [8], [9], [13] and authority and accountability from PDE [6], [7]. Future work will seek to better understand how students understand and respond to agency and how theories of agency from science education may be more fully adapted for EER.

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