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Abstract

Engineering identity plays a key role in the educational experiences of undergraduates majoring in engineering fields. Design thinking pedagogy can enhance engineering identity. However, little is known about how design-thinking pedagogy influences engineering identity development within an online environment, and specifically how this looked during the COVID-19 pandemic. The purpose of this qualitative study was to understand how a design thinking-oriented engineering course delivered online supports undergraduate students' engineering identity development during the COVID-19 pandemic. Researchers collected 63 observations, totaling approximately 79 hours of observation of an embedded systems engineering course. Findings revealed the importance of language and framing in shaping engineering identity in online learning spaces. In addition, online student-faculty interactions were seen as an area of growth. Finally, the study found that online spaces can complicate opportunities for engineering identity performance. This study has implications regarding intentionality and online learning. To enhance engineering identity, faculty and administrators should consider how they use language to frame their courses and create meaningful student-faculty interactions.

Introduction

Developing and maintaining an engineering identity plays a key role in the educational experiences of undergraduates majoring in engineering fields (e.g., Hughes et al., 2019; Godwin et al., 2016; Rodriguez et al., 2020). Engineering students who do not see themselves as potential engineers are at higher risk of switching majors or dropping out of college (Geisinger & Raman, 2013; Meyer & Marx, 2014; Pierrakos et al., 2009; Walden & Foor, 2008). Due to the COVID-19 pandemic, disruptions to normal operations were ubiquitous, and educational institutions were not spared. The uncertainty brought forth by the pandemic meant that many instructors were forced to abruptly adapt their courses to an online format, and students suddenly had to engage with their coursework in a manner that was likely unfamiliar to them, especially in highly experiential and collaborative disciplines like engineering (Park et al., 2020). This swift push to an online format also changed how students and faculty interact, and opportunities for collaboration with peers shifted. These interactions and collaborative experiences, which were beneficial to engineering identity development – because they allowed

students to demonstrate competence, perform their engineering identity, and be recognized by others as someone who does engineering work – were disrupted (e.g., Lockhart et al., 2024).

Design thinking has emerged as a pedagogical strategy in which educators can encourage engineering students to engage with the curriculum and develop a sense of connection to their work (Luka, 2014; Razzouk & Shute, 2012). In the context of engineering, design thinking is expansive in its consideration of users, resources, and multiple solutions. Design thinking as a pedagogy is one strategy in engineering education described as beneficial to students in helping them break down design processes and use higher-order thinking skills (Li et al., 2019). Scholarship also demonstrates that design thinking pedagogy and design activities have the capacity to enhance engineering identity (Rohde et al., 2019; Rodriguez et al., 2020). Students who might not otherwise feel a sense of engineering identity can, through design-thinking pedagogy, start to see themselves and be recognized as engineers.

However, little is known about how design-thinking pedagogy influences engineering identity development within an online environment, particularly in an embedded systems course offered to middle years undergraduate students. While scholars know that engineering identity plays a key role in the educational experiences of undergraduates majoring in engineering fields and that design thinking pedagogy can enhance engineering identity, little is known about how design-thinking pedagogy influences engineering identity development within an online environment. Although research indicates that design thinking can be used to create online courses broadly across content areas (Anderson et al., 2017), the unique nature of learning within engineering and the widespread need for broadening participation in engineering create a need to understand how design thinking pedagogy within online contexts influences engineering identity development.

This study was guided by the following exploratory research question: In what ways does a design thinking-oriented engineering course delivered online during the COVID-19 pandemic support or hinder undergraduate students' engineering identity development? To answer this exploratory research question, we have situated our work within the current studies of engineering identity, design thinking, and online learning. We utilized Gee's (2001) discussion of role identity concepts as well as engineering education research on the dimensions of engineering identity (Godwin, 2016), including elements related to engineering competence/performance, interest, and recognition.

Literature Review

Engineering Identity

Engineering identity refers to the perception of oneself as someone who possesses the interests, knowledge, skills, and behaviors of an engineer. Engineering identity refers how engineering students come to know themselves and be recognized as the kind of individuals who engage with engineering concepts and work (Rodriguez et al., 2020). Furthermore, engineering identity also influences how engineering students come to and experience the field as well as the designs that they create (Rodriguez et al., 2018).

During professional identity formation, engineering students may move from being outsiders to insiders through a process that requires them to negotiate themselves as professionals by balancing their own definition of self with their definition of the profession (McCall et al., 2019). Discipline-specific processes, norms, and cultures may be important to the discussion of engineering identity (Godwin, 2016; Espino et al., 2020). Studies have shown that engineering interest, recognition, and performance/competence significantly predict engineering identity (Patrick et al., 2018). According to Godwin (2016), students' engineering identities are comprised of feelings and demonstrations of performance/competence, subject-related interests, and feeling that others recognize one as an engineering person. Under this view, identity is not a static condition but rather an ever-evolving state that is simultaneously shaped by internal and external circumstances and experiences. Developing and maintaining a solid engineering identity can provide students with the confidence and motivation needed to continue pursuing an engineering career and requisite skills and to accept the role of an engineer (e.g., Pierrakos et al., 2009). Research suggests that attrition rates are higher for students who do not self-identify as engineers (Geisinger & Raman, 2013; Meyer & Marx, 2014). Thus, engineering identities are crucial to the retention and success of engineering students.

Engineering identity can become complicated when students do not see alignment between their own values and perceptions of what it means to engage with engineering (Lakin et al., 2020). Mann et al. (2009) found that several factors positively impacted engineering identity development, including interaction with peers, availability of mentors, and working in teams to complete realistic projects. Du (2006) similarly found that problem-based learning was beneficial to students' engineering identity development. However, in this same article, the author also notes potential identity complications from problem-based learning related to the masculine culture in engineering communities. Each of these factors is notable in that they provide students with opportunities to perform their engineering roles and be recognized as engineers by faculty and peers. Other research has shown the importance of families, identity-based organizations, and intersecting identities as important to the engineering identity development process (Rodriguez et al., 2022). Engineering identity development is highly influenced by other identities, such as race and gender, as well as an ability to resist against oppressive structures (e.g., Ross et al., 2020; Rodriguez et al., 2019; Rodriguez et al., 2020). Scholars differ over the importance of individual engineering identity elements (e.g., recognition, competence/performance), particularly for marginalized communities who may experience these elements differently than members of majority communities (e.g., Verdín, 2021; Rodriguez et al., 2020). In contrast, Fleming et al. (2013) found that engineering coursework that was exceptionally challenging undermined the development of students' engineering identities. Engineering identity is often correlated with a student's mental health as well as feelings of inclusion, particularly for women, who may experience gender-specific stress (Jensen & Cross, 2021). However, pedagogical and curricular alignments with engineering identity elements have shown the most promise in the formation of engineering identities at the undergraduate level (Winberg & Wingberg, 2021).

Design Thinking & Connections to Engineering Identity

Over the past twenty years, there has been a significant increase in the scholarly and practical interest with design-thinking concepts, particularly as a tool towards creativity, innovation, and problem-solving of real-world

challenges (Baker et al.., 2020; Boyle et al., 2022). Recently, there has been a proliferation of literature which has focused on educational settings, design frameworks, and online learning (Bhandari, 2022). As Bhandari (2022) points out, there remains a need to explore design thinking in online learning platforms as practitioners consider existing education models. Design-thinking has been implemented within engineering curricula in a variety of ways, including through coursework, short programming, workshops, and culminating capstone projects (Boyle et al., 2022; Crites et al., 2020; Dym et al., 2005; Lee et al., 2018).

Design thinking focuses on the abilities of engineering students to design solutions for complex problems (Dym et al., 2013). And, while some scholars believe that it is both difficult to learn as well as teach (Dym et al., 2013), it has been offered as a pedagogical tool that may impact engineering identity development. Design thinking is a transdisciplinary approach to problem-solving (Dorst, 2011) that, in a general sense, involves addressing all components of the problem (Luka, 2019). The process of design thinking involves assessing all aspects of the problem, generating several possible solutions to the problem, and exploring the efficacy of those solutions through deliberate testing (Yilmaz et al., 2016). Design thinking is a collaborative, holistic, and iterative approach that encourages the exploration of a wide range of resources and problem solutions Yilmaz et al., 2016).

The empathetic, human-centered nature of design thinking allows for a greater sense of connection to the work being done to solve the problem and to the people associated with the problem, including others who are also attempting to solve it and all who are affected by it. Systematically considering all persons and angles associated with the problem in this way provides a sense of meaning by contextualizing the overarching impacts of the work being done. Moreover, the flexible mindset that is fostered by the design thinking approach is likely to prepare engineering students for a field that is continuously evolving (Channell, 2018) with the ever-changing demands of a technological society (Wrigley & Straker, 2017). As Li et al. (2019) stated, "design thinking can and should be viewed as a model of thinking in school education to help nurture and develop for every student in the twenty-first century" (p. 97). Furthermore, design thinking within classrooms give space for innovation and creativity, particularly in instances where abductive, rather than merely inductive or deductive, reasoning is present (Koskela et al., 2018). While deductive reasoning might lead an engineering student to move from general ideas to more specific conclusions and inductive reasoning might encourage that same student to draw conclusions from specific to the more general, abductive reasoning might push engineering students to propose several explanations and choose the one that is most plausible. This type of reasoning aligned with design thinking encourages engineering students to think more creatively and draw upon their range of background knowledge, identities, community ways of knowing in ways that traditional reasoning may not.

Design experiences can enrich students' engineering identities by providing real-world design opportunities that enable them to develop competence and encouraged self-identification as an engineer (Rohde et al., 2019). However, when design thinking pedagogy was poorly implemented, students struggled to see the relevance of design thinking to their engineering abilities and often passed on design thinking opportunities (Rodriguez et al., 2020). Design-thinking implementation can be improved through (1) utilizing mapping to make curricula relevant and responsive to the environment, (2) committing to continuous enhancement of the design process, (3) integrating opportunities for design-thinking pedagogical innovations, and (4) focusing on sustaining quality

strategies (Dym et al., 2005). Research has demonstrated that first-year engineering students often have higher levels of perceived design thinking ability than their upper division peers (Coleman et al., 2020), suggesting that the field might benefit from better implementation of design thinking pedagogies across engineering curricula. Such efforts to document instructional heuristics in design thinking have revealed a with range of approaches, including using it to encourage failure, promote collaboration, and integrate new content as well as to create connections between topics and promote professional formation (Fila et al., 2018).

Design Thinking and Online Learning

Like design thinking, the thoughtful and strategic implementation of online learning is key to its success. The challenges posed by an online modality in higher education are well-documented. In a review of the literature on the topic, Kebritchi et al. (2017) concluded that the central issues posed by online learning can be categorized as those related to online learners (e.g., active participation, students' expectations for online courses, preparedness), challenges faced by online instructors (e.g., transitioning from a face-to-face to an online format, adapting one's teaching style), and the development of online educational content (e.g., the integration of multimodal-al presentation styles). The conditions incurred by the COVID-19 pandemic only served to exacerbate these challenges. There was not much time to carefully design online courses as educational institutions were rapidly shutting their doors indefinitely, and campus support that would typically be available for those faculty members with fewer technical skills was likely to be oversaturated and understaffed for such an event. For students, the severe reduction in social interaction and on-campus experiences were shown to negatively affect attitudes toward their education during this time (Mucci-Ferris, 2021). It is feasible that these changes in the frequency and quality of interactions between students, faculty, and peers could negatively impact students' engineering identities via fewer opportunities to demonstrate their competence or be recognized by their peers and instructors as engineers. While these factors may paint a discouraging picture, general findings regarding the effects of the shift to online learning during the pandemic provide a more positive outlook. Some research suggests that this transition positively impacted faculty and students' creative problem-solving skills (Hodges et al., 2020), technological aptitude, and time management skills (Mucci-Ferris, 2021).

The present study was spurred by the uncertainty surrounding the impact of so-called emergency remote teaching (Hodges et al., 2020) on engineering identity development, particularly within the context of design thinking pedagogy. Given the recency of these events, there is limited literature concerning the implementation of a design thinking approach to online courses within the context of the COVID-19 pandemic. However, the few studies that have addressed the topic are promising, with some suggesting that a design thinking approach is particularly well-suited for rapidly changing conditions such as those experienced during the pandemic (Thakur et al., 2021) or, more generally, those inherent to an evolving, increasingly online educational environment. The results of these studies point to several conclusions – adaptability from all involved parties is paramount, extra effort is needed from both students and instructors to develop and maintain connection and communication, certain aspects of the online environment (e.g., discussion forums, virtual focus groups, online knowledge hubs) can be strategically leveraged to maximize educational and inter-personal outcomes, and reliance on existing solutions is not only acceptable but necessary (see Cankurtaran & Beverland, 2020; Thakur e al., 2021).

Conceptual Framework

Our study is grounded in Gee's (2001) discussion of role identity concepts as well as engineering education research on the dimensions of engineering identity (Godwin, 2016). Gee (2001) characterizes identity as "being recognized as a certain 'kind of person" (p. 99). The conditions under which this recognition can take place may change depending on what identity is being recognized (e.g., gender identity versus engineering identity) and who or what is doing the work of recognition (e.g., another engineer or an institution). Individuals negotiate their identities in a myriad of ways, but the crux of the matter is that who and how a particular identity is recognized is crucial (Gee, 2001). Identity is also often linked to motivation for pursuing an engineering career pathway (Godwin & Kirn, 2020). However, engineering identity can be complicated by traditional stereotypes and representations of what it means to be an engineer and students must figure out how they "fit" within the engineering space (Verdín et al., 2018). Drawing upon these concepts, we honed in on three elements of engineering identity: recognition (being recognized by others as an engineer), competence/performance (demonstrating understanding, doing the work of engineering), and interest (a desire to be an engineer; Godwin, 2016).

We utilized these elements to observe a design thinking-oriented engineering course delivered online during the COVID-19 pandemic with the intention of understanding how this course supports undergraduate students' engineering identity development. To do so, we observed places in which language, student-faculty interactions, and the online learning environment either supported or hindered the development of an engineering identity.

Method

This general exploratory qualitative study (Merriam & Tisdell, 2016) is part of a larger project funded by the National Science Foundation specifically looking at the incorporation of design thinking pedagogy into a middle years course. A general exploratory qualitative approach was selected to more fully understand the interconnectedness and complexities that occurred. Qualitative research allowed for us to see these phenomena in their natural context and allowed us to gain a deeper understanding of the human experience and everyday realities associated with our research questions.

The exploratory nature of our qualitative research enabled to gain a broad understanding of our topic and recognize important patterns and possible interpretations of the data which can inform future study designs, both within and beyond our research team. Our observations, described in more detail below, tended to focus on faculty lectures and limited engagement with students. Observations allowed us to gain access into the classroom setting and see situations from a perspective of wholeness, rather than in discreet pieces.

Research Site

The research took place within the electrical and computer engineering (ECE) department at Iowa State University, a predominantly white, research-intensive land-grant institution in the Midwest region of the United

States. The middle years course selected for redesign around design thinking was embedded systems. The embedded systems course included content related to design flow, microcontrollers, system-level debugging, and programming and designing applications, as well as the professional roles and responsibilities of embedded systems careers. The embedded systems course was a key middle-years course which has the potential to address each of the ABET student outcomes. For institutional and departmental purposes, this course was particularly concerned with meeting the following ABET General Criterion 3. Student Outcome (c) which emphasizes that the course must focus on: An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

The redesign of this course included a shift towards getting students to broaden their analysis and design skills to create solutions that work for individuals and society as well as encouraging students contextualize course concepts as socio-technical-minded engineers. Throughout the course assignments, students were asked to engage with the design-thinking process (e.g., empathize, define, idea, prototype, test) as they learned about embedded systems technical knowledge. Several key elements were discussed within the course to encourage design thinking: tolerance of ambiguity, seeing design as a form of inquiry, utilizing systems and "big picture" thinking, decision making strategies, and thinking within group settings. During the COVID-19 pandemic, this course, along with the majority of ECE departmental courses, were offered online with the opportunity to either engage synchronously or asynchronously with recorded videos.

Data Sources

We utilized the study's conceptual framework to analyze how a design thinking-oriented engineering course delivered online during the COVID-19 pandemic supported undergraduate students' engineering identity development. The research team conducted observations of the embedded systems course. These observations included weekly meetings for two course sections taught by the same instructor. The observations were recorded each week and placed on YouTube for students to view either live or after the fact. We engaged in data collection strictly as observers and did not engage with the space as participants in any capacity. One limitation to our data collection is that we also did not have access to the chat of the online classroom, so we relied heavily on the instructor explicitly saying he was answering a question from the chat. Each class meeting lasted 75 minutes, and we collectively conducted 63 observations, totaling approximately 79 hours of observation time over the course of the semester.

An observation protocol was developed to ensure some continuity among the observers, specifically drawing their attention to the elements of engineering identity development (i.e., recognition, competence/performance, interest). The observation protocol allowed for the making of observations about these elements, including what occurred (e.g., actions, activities, interactions) and by or to whom (i.e., student-to-student; student-to-faculty). In addition, the observation protocol allowed observers to note major take-aways from the observation, future areas to investigate, and remaining questions to answer. The protocol was co-developed by the research team based on the conceptual framework (i.e., Gee, 2000; Godwin, 2016) concerning engineering identity development. The

observation protocol also included a final section in which observers could note possible interpretations as well as any areas for future exploration by the team. Observations were completed by research team members utilizing audio and visual recordings of each class. Recordings of the class were available to the research team after the class occurred. Our team of observers was representative of diverse identities, including a range of genders, race/ethnicities, nationalities, and professional backgrounds. Observers filled out an observation protocol for each of observation made which were made available to everyone on the research team.

Data Analysis

To ensure trustworthiness, the research team took several steps throughout the research design and data analysis processes (Creswell & Poth, 2016; Roberts et al., 2019). The research design sought to improve internal validity through prolonged engagement and persistent observation of the research site. These elements of the research design enabled us to understand the setting, interactions, and elements of the course we observed over time.

Observation protocols were read several times for deeper understanding. The data were coded using a codebook created from *a priori* codes based on relevant literature as well as the conceptual framework; inductive codes were developed as needed. Codes included, but were not limited to: design-thinking, online learning, language, competence, interest, performance, recognition. The research team coded all observation protocols using qualitative software in which elements of the observation were tagged with relevant codes. From this coding, utilized thematic analysis to determine salient themes across the data. To generate themes, the research team combined several codes into preliminary themes that addressed the research question. From here, the research team reviewed the preliminary themes, taking care to refine ideas, bring more specificity, and clarity to each. From these steps, we defined the themes that are presented below.

We held periodic meetings to discuss our interpretations and document the data analysis process, including coming together to engage in a constant comparative method of data analysis. We also wrote analytical memos based on our notes from the data collection and met as a team to discuss what patterns stood out to us.

Furthermore, the research team explored their positionalities, including their various insider and outsider statuses, and prior experiences with STEM and engineering, more specifically. Two members of the research team served as faculty-level social scientists on the larger funded NSF project and have been engaged with the department for several years. Both have active STEM education research agendas and a commitment to diversity, equity, and inclusion (DEI) within higher education. The other three members of the research team served as graduate students affiliated with the funded project and have been engaged, in varying ways, in the data collection, analysis, and writing processes.

Findings

The research team sought to understand how a design thinking-oriented engineering course delivered online during the COVID-19 pandemic supports or hinders undergraduate students' engineering identity development.

Through observation of the online embedded-systems engineering course during the pandemic, three themes emerged which highlight (1) the importance of language and framing in shaping identity in online learning spaces, (2) online student-faculty interactions as an area for growth, and (3) how the online space complicates opportunities for engineering identity performance.

Importance of Language and Framing in Shaping Identity in Online Design Thinking Learning Spaces

During the pandemic, many undergraduate engineering college students went entirely online for their education. For many students, contact with others was extremely limited, given the uncertainty around health concerns, particularly for students who were more at-risk for COVID-19 health related complications. As such, online learning during the pandemic represented a key touchpoint that engineering students had with others in their college-going process as well as the broader world.

Faculty can play a key role in students' development of engineering identity through the language choices they make in an online lecture. Reframing conversations of course design that are built around the practices of design thinking can provide opportunities to support students in their development of engineering identity. In particular, the ability of a faculty member to practice and model empathy through normalization of struggle (e.g., "if you're struggling to work this problem that's fine") can draw on the human centered approach essential to design thinking. Similarly, a faculty member's positive affirmation (e.g., "interesting question") when answering a question in the chatbox during an online lecture, may invite additional questions and encourage students to build competence and engage in building their own engineering identities. For instance, this language seems to support students' questions and in turn potentially encourages other students to participate in both the define and ideation process of design thinking. Faculty language choice and integration of design-based thinking practices and principles focused on empathy, centered in human connection can support students, specifically those who are unfamiliar with the content or who are experiencing challenges with the process. While the inclusion of design thinking language and modeling of these processes could be validating and enhance recognition, the lack of such supports could also be a source of frustration for students. Students may feel invalidated leading to potentially complicating feelings of recognition, perceptions of their technical competence, and, ultimately their engineering identities. In the example below the instructor described the concept of enabling the interrupt in an Interrupt Service Routine (ISR) setup; the instructor stated:

> …it's a very simple pattern for doing things. Again, this is the formula they give you in the book to figure it out, but it's pretty straightforward. If you know this picture, pretty quickly you can figure it out…

In contrast to the statements above this one does not model the design-thinking process that students should be working towards. For instance, the ideals of design thinking require the leader to engage in deep thinking processes where the end user is the focus. Although this is content that the students will be required to know (and likely eventually know "quickly") it is problematic to veer from the pillars of design thinking in the process. Some finetuning or tweaking of the language in this example may provide more support and show outward empathy to students who are developing their engineering identities or questioning their knowledges or abilities. While the

instructor, or others with developed engineering skills or content knowledge may find this lesson "simple," "straightforward," or be able to "quickly" complete tasks, such framing may discourage engineering students from gaining competence or believing in their ability to perform engineering tasks, for fear that any uncertainty they may have deems them less of an engineer.

In a separate observation, a faculty member stated, "…I'll expect if I gave this to you this would be pretty straightforward to deal with," further reiterating the expectation that students should not only know the material but be able to apply that knowledge to the course's assignments with ease. Similarly, in an online lecture the faculty member commented that "…from a software perspective, it's very easy. Even middle school people can understand the idea." While there are a myriad of potential issues within this statement there is at the very least the lack of understanding or modeling or the collaborative process involved in design based thinking. Additionally, and perhaps even more front and center for students engaging in this space that do not understand the idea or are questioning the software being discussed there are potentially feelings of being "less than" a middle school student regarding engineering identity or understanding. Such actions intimate that a lack of competence/performance automatically translates to denial of an engineering identity.

We noted that in nearly every observation, the instructor used language to downplay the difficulty of the material. To support students in their engineering identity instructors, need to provide not only a nurturing, human-centered, environment, but also one that supports student collaboration and development in a holistic nature. This language used repeatedly by the instructor along with a lack of deign thinking process modeling or integration could add to struggling students' anxieties about the course and its content in ways that could negatively impact their engineering identity development. Due to the online nature of the course, particularly within the pandemic, students may only have experienced these faculty-student interactions, rather than other opportunities for interactions that might have been possible during typical semesters or if the course was offered in person.

Online Student-Faculty Interactions as an Area for Growth in Design Thinking Approaches

The study found that online student-faculty interactions had the potential to both enhance engineering identity as well as detract from it. We contextualize these findings this study through the lens of a large in person lecture course that has been moved to an online environment necessitated by university COVID-19 precautions. Rather than a thoughtful, integrated, or systematic move towards online learning, the pandemic forced faculty to within a matter of weeks move the embedded systems course online as best they could. Both engineering faculty and students were largely unprepared for shifting design-thinking approaches to online contexts or how course stakeholders might interact with each other, let alone considering how these changes influenced engineering identity.

This change in learning modality limited student-faculty interactions to those that occurred in the chatbox. Faculty members who previously may have been able to engage with students through design process practices in an in-person environment were now forced to quickly and purposefully plan out these experiences for a much different online experience. As we reviewed previously, using a design thinking model with students could provide them

with opportunities to not only practice their own skills in this area but also build on their engineering identity. In turn the lack of these models and processes and the inclusion of invalidating experiences with faculty could complicate that process for students.

Following Clements et al. (2020) in understanding that for students "negative interactions with faculty influenced their ability to recognize themselves as competent, which in turn influenced their learning and development as an engineer" (p. 12), we interrogate the impact of online interactions between faculty and undergraduate engineering students. For example, in one online interaction, the faculty member seemingly made assumptions that various tasks in the class were "simple" since concepts were previously introduced:

> … You'll see that there's nothing, no new features you're doing…you're basically doing a simple mission, where your mission is to develop an embedded application that has the cybot autonomously, detect the smallest or thinnest object on the test course.

This interaction could detract from a student's engineering identity development as it insinuates that previous learnings, once mastered, are seen, or described as simple. In addition, there is a lack of design thinking process or language evident in this interaction. Specifically, when we think of the process as iterative with opportunities to take previous learnings and not only build on them but also think of them in new ways based on the context of the design, few things can be described as simple. In this case the faculty member seems to assume that students understand or have mastered the content when in fact there could be an opportunity for collaboration through breakout rooms or another interactive tool. The phrase "no new features" itself is at odds with the pillars of design thinking such as the ability and desire to shift the problem-solving approach and process to potentially engage with the same tools in new ways or for new purposes.

Observations of students and faculty interactions also demonstrated a degree of externalizing from the faculty member.. In one online lecture session, the faculty member conducted a debrief of students' recent quiz results. Through the debrief process there was a heavy emphasis on the role of the student in their own lack of competence as perceived by the faculty:

> … In terms of the analog digital conversion bonus questions, it seemed like more people than I would have hoped were struggling with that. So, mostly a sign of not having had a chance to read over that stuff in this year's textbook, most likely. That being said, of the bonus questions, I would say, umm, one was meant to be pretty straightforward. The second one, was, wouldn't say trickier, but it was checking to see if you really understood what was happening…

In multiple instances, the faculty member assumed, whether correctly or not, that students had not read the course material, and thus, performed poorly on the quiz. In this example there seems to be a heavy reliance on the textbook and more traditional teaching methods when students may find newer, more innovative processes beneficial to their learning and development of engineering identities. There was not a process of discussion or collaboration, or empathy modeled or displayed in these interactions.

A theme noted throughout our observations was that a limited number of questions were asked by students. In real-time, faculty further related that they were "a litte surprised" at not getting more questions. This lack of engagement and question asking could be due to several different factors. Students may not have felt comfortable asking their questions in the large lecture online format. The main way of asking questions was to type them in the chat box online. Additionally, students may have felt intimidated or nervous to demonstrate a struggle with building competence or showing a misunderstanding of content or engineering practices, particularly when faculty stated during the same lecture that their work should be simple.

The hesitation to ask questions could also show a disconnect of the design thinking process within the online lecture format. The low participation of students asking questions might be due to their lack of knowledge regarding the use of online design thinking pedagogy as well. The questions from the instructor tended to be geared more towards rote memorization or stagnant thought processes rather than the iterative and collaborative ideals present in design thinking spaces. The aforementioned quote leads to the idea that possibly the professor was looking for design-based practices or ideas but had not prepared students in this way.

Using Design Thinking Processes to Support Engineering Identity Development in Online Lectures

Online spaces, particularly those with large class sizes, similar to this course may shift or complicate the how students demonstrate their competence with the material in meaningful ways. In this study, the findings demonstrate that students' engineering identity development is further complicated by the online learning environment. For example, in a large online lecture it becomes very difficult for students to demonstrate competence or apply course concepts in a meaningful way. Faculty members may also have difficulty gauging whether students continue to gain competence. The nature of in-person learning environments provide faculty with opportunities to gauge understanding by seeing student and utilizing their verbal and non-verbal cues as learning is taking place. In contrast during an online lecture students may or may not have their camera on, making that engagement and connection at times impossible.

The actions of moving a large online lecture course from in person to an online environment are multifaceted and have implications beyond the access point. For the undergraduate students in this course, we found that there was also a loss of the opportunity to practice and perform their engineering identities. Further complicating the move online was the impact of COVID emergency procedures and implications for students. For example, students may have had extra or new responsibilities at work or home due to illness of others in their circles. This may have meant that they were accessing lectures through a recorded means and thus losing the option to ask questions in a "live" sense altogether.

Discussion

Although the study took place during the COVID-19 pandemic, it has implications for our classrooms of today as well as in the future. Although online education was in place at many institutions before the pandemic, interest and need for these offerings has increased within engineering education (Asgari et al., 2021). This study answers

the call for more studies needed to explore design thinking in online learning platforms (Bhandari, 2022). As online learning continues to grow, this work suggests that even though implementation issues around design thinking have been a concern from early work (Dym et al., 2005), how individuals, departments, colleges, and institutions actually "do" design-thinking continues to be a challenge, as evidenced with this study. Furthermore, the context of this study within the middle years courses (embedded systems) is a departure from what we know about first-year students and senior-year engineering students and their design thinking experiences (e.g., Coleman et al., 2020). While scholars continue to study first-year and later stages of engineering students' experiences, the important middle years are just starting to gain traction as an important area of study (Han et al., 2018; Laugerman et al., 2019). This study suggests that middle years courses, particularly those in online platforms, may be areas ripe for design-thinking attention and innovation, both among scholars as well as practitioners.

This study supports prior research regarding the importance of instructional heuristics, particularly those around design-thinking and promoting professional formation of engineers (Fila et al., 2018). It extends this work by encouraging the field to consider implementation issues of design-thinking and engineering identity, particularly within the online settings of today's student. It clearly articulates the need for instructors to have a design-thinking informed infrastructure for courses as well as the need to be responsive within the active learning process. Because this study took place during a tumultuous time in our world's history, it also serves as a site of lessons learned regarding the implementation of design-thinking and concerns around engineering identity. Although we may hope for a future of health and prosperity, pedagogical preparation for calamity and challenges may be prudent in order to best serve engineering students during those times.

Findings revealed the importance of language and framing in shaping engineering identity in online learning spaces. In addition, online student-faculty interactions were seen as an area of growth. Finally, the study found that online spaces can complicate opportunities for engineering identity performance. While most engineering identity research either explicitly (or implicitly) takes place in-person or does not dis-aggregate by online setting (e.g., Espino et al., 2020), the current study opens up further discussion for how these settings might shift how we think about engineering identity development. This study has implications regarding intentionality and online learning. To enhance engineering identity, faculty and administrators should consider how they use language to frame their courses and create meaningful student-faculty interactions.

This study questions whether the online setting enables students to move from being outsiders to insiders like other studies have suggested (McCall et al., 2019), or if students might be pushed even farther towards outsider status. Despite the educational promise of pedagogical and curricular alignments with engineering identity (Winberg & Wingberg, 2021), this study demonstrates that this promise is not without complication. Previous research has demonstrated the importance of cultivating an engineering identity (e.g., Godwin, 2016) and the promise of design thinking pedagogy. Given the scant research on the influence of design thinking pedagogy on engineering identity, this study serves to further explore how online delivery may require more intentional thought and design. In particular, this study highlights the importance of language and framing to the online design thinking learning space. An online format may not easily allow for additional affirming student-faculty interactions (or even peer-to-peer interactions). We noted moments where the instructor tried to normalize struggle

and to appear approachable, and the acknowledgement of struggle may help students whose sense of competence and confidence may be lacking. Understanding that achieving competence is not always a linear process may help students with their engineering identity development. Yet there were also times where the difficulties of assignments or content was downplayed.

These types of moments could easily happen in face-to-face meetings as well as online spaces; however, since students' cameras were often turned off, it was likely much more difficult for the instructor to read students' non-verbal cues and gauge if more clarification was needed students were nameless, faceless, interactionless black boxes who were often reminded that their development as engineers was insufficient yet had few ways to demonstrate their competence or perform as engineers or work in collaborative design-thinking aligned contexts where they might be recognized as engineers.

Furthermore, there was not a process of discussion or collaboration, or empathy modeled or displayed in these interactions. What this study suggests is that in order to incorporate design thinking in online spaces in ways that may boost students' engineering identities, an instructor may have to intentionally consider what can be effectively incorporated and when. Put another way, some content and activities may not hit all six domains of design thinking or speak to students' interest, performance, and competence. Careful planning may help instructors thread in these pieces at various points throughout a class. While this speaks to the importance of pedagogical choices by faculty members (similar to Rodriguez et al., 2020), this study pushes scholars and practitioners to consider the complexities of connecting design thinking and identity, particularly within a middle-years learning setting that is already heavily loaded and rigorous.

To overcome at least some of these challenges, modeling design thinking with students an instructor might take this opportunity to first better understand the users of the quiz (students) to interrogate what issues might be present for them. In addition, this could be a chance for faculty to show how to brainstorm and explore possibilities for change and support students engineering identities. For instance, collaborating with students could have shown issues such as instructor methods, course delivery modality, or other pandemic hardships causing students to perform poorly on the assessment. This study makes a connection between engineering identity literature (e.g., Godwin, 2016; Rodriguez et al., 2020) and design literature (Koskela et al., 2018) particularly around what it might mean to support design thinking as a core part of engineering identity.

In particular, the abductive reasoning elements of design thinking may encourage engineering students to be more creative and innovative in their design processes and leverage their diverse backgrounds, knowledge, and experiences. Leveraging these elements may be particularly important as practitioners look for ways to create coherence between an individual's engineering identity and the design process. Overall, there was also little recognition from the faculty members that students were developing their design thinking competence within the context of a worldwide pandemic. Rather than considering how design thinking in an embedded systems course might be complicated by the online delivery and pandemic, the course reiterated that students were responsible for their development as engineers.

Finally, this study demonstrates how a design thinking-oriented engineering course delivered online during the COVID-19 pandemic could hinder undergraduate students' engineering identity development, particularly if areas such as language, student-faculty interactions, and online pedagogies are not properly engaged. These elements are potential levers for change regarding ABET-defined student outcomes, such as the one addressed with this embedded systems course, which focused on designing within realistic constraints. Without attending to elements such as language, student-faculty interactions, and online pedagogies, students cannot build and maintain strong engineering identities to realize and fulfill their potential as engineers. Students who have a clear understanding of their own engineering identities may more readily engage with engineering tasks and utilize their own identity experiences to empathize and meet the needs and constraints of the design projects and communities around them.

Conclusions, Limitations, and Implications for Practice

The purpose of this exploratory qualitative study was to understand how a design thinking-oriented engineering course delivered online supports undergraduate students' engineering identity development during the COVID-19 pandemic. Through observation of the online embedded-systems engineering course during the pandemic, three themes emerged which highlight (1) the importance of language and framing in shaping identity in online learning spaces, (2) online student-faculty interactions as an area for growth, and (3) how the online space complicates opportunities for engineering identity performance. This study has implications regarding intentionality and online learning. To enhance engineering identity, faculty and administrators should consider how they use language to frame their courses and create meaningful student-faculty interactions.

Limitations and Implications for Future Research

As with any study, this study had several key limitations. First, the study is limited to observable perceptions of the engineering identity development process. Given that we did not have the chance to fully observe students – as most had their cameras turned off – we are somewhat limited in our interpretations. Future studies might endeavor to study online design thinking environments in which students are required to turn on their cameras, or perhaps interview students about their behaviors and experiences with these courses to gain a more robust picture of the engineering identity development process. Relatedly, future studies should also consider pairing observation data of the classroom setting with student interviews to more fully understand the engineering identity development process.

Second, this study represents one, cross-sectional point in time that was, with all hope, unique in nature. Future studies might seek to understand how design thinking in online learning spaces looks beyond, or as we continue to transition out of, the COVID-19 pandemic. In contrast, scholars might ask students or faculty to compare their experiences of design thinking and engineering identity development within both settings to contrast these experiences more fully. In addition, given the continued rise of online offerings post-COVID-19 pandemic, scholars might also consider investigating a broad range of online course offerings to understand how design-thinking manifests within varying courses in engineering programs.

Lastly, this study was limited by our desire to focus broadly on the design thinking approach, rather than specifically on any one element. Scholars might seek to interrogate specific parts of the design thinking approach (e.g., empathy, ideation, prototype) to understand which elements might be complicated within an online setting. This might provide additional information regarding which design thinking aspects could better inform engineering identity within online spaces.

Implications for Practice

To enhance engineering identity development, faculty and administrators may have to further consider how they use language to frame their courses and create meaningful student-faculty interactions. This might include a review of how design thinking concepts are introduced within the online course and its course materials as well as how faculty members portray the concepts in real time with students. Furthermore, faculty members might consider a review of how their design thinking courses connect with engineering identity and what ways they might tailor the class to improving aspects of that development.

The COVID-19 pandemic involuntarily pushed institutions to expand their online course offerings. While many institutions have reincorporated in-person course offerings, online options are here to stay. As such, the debate around engineering course modality has continued post-COVID-19. Part of this continued conversation should include elements of design-thinking and engineering identity, similar to prior conversations based in in-person offerings.

This study has implications around how engineering instructors create and refine design-thinking online learning environments. Within this study, we saw that many students left their cameras off, limiting their interaction in this online space. This calls into question whether specific guidelines for engagement and building community in online spaces should be introduced by the faculty member.

We contend that modeling the course, including lectures, through design thinking processes would support students and instructors in processes that helped to grow the skills of students in their engineering identity development. For instance, if students were struggling with the online environment the instructor could model the understand, explore, materialize process. More specifically challenges of COVID19 and shifting learning online in these ways were new to many (students and teachers). Using this real-life problem as a way for students to understand the design process could provide more context for learners. In turn, instructors could have engaged students in engineering content after building relationships through mutual empathy and working towards a common goal.

This conversation transcends the pandemic as online learning continues to proliferate the higher education landscape and as demographics within engineering continue to bring a more diverse group of students into the classroom. In looking towards the future, this study represents an opportunity to open conversation regarding how online courses, design thinking, and engineering identity have the potential to work together to create spaces in which students feel more like engineers.

Notes

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