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Abstract

Engineering identity plays a vital role in the persistence of engineering students, yet limited research exists on how particular pedagogical approaches influence engineering identity at the college level. This qualitative case study explored how undergraduate student perceptions of design thinking pedagogy influence computer, electrical, and software engineering identity. The study found that design thinking pedagogy reinforces the recognition of an engineering identity, particularly for those from historically marginalized groups (i.e., women, people of color). Intentional implementation, including organization and framing of design thinking pedagogy, was an essential foundation for fostering student interest in the course and connecting to their role as engineers. This study suggests that design thinking is a fruitful area to explore to create more inclusive engineering environments. This study's findings will assist educational stakeholders in understanding the design thinking pedagogy and engineering identity experiences of CES undergraduate engineering majors. Findings may encourage institutions to view the engineering curriculum in terms of identity development and understand how intersectional identities influence the ways students, particularly those from marginalized backgrounds, experience the environment.

Introduction

Developing and maintaining an engineering identity plays a key role in undergraduates' educational experiences majoring in engineering fields. 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). Researchers found that students with marginalized identities are more likely to encounter challenges in developing their engineering identities (Du, 2006; Foor, Walden, & Trytten, 2007; Hughes, 2017). These challenges result from structural inequities, but students often internalize and express themselves as the problem rather than with the field (Carlone & Johnson, 2007; Shanahan, 2009).

The nature of engineering identity is not entirely exact, and there is little consensus about which interventions are successful in helping students develop it. However, design thinking has emerged as a possible way for educators to encourage engineering students to engage with the curriculum and develop a connection to their work (Luka, 2014; Razzouk & Shute, 2012). Design thinking is an iterative process in which designers focus on a problem, generate ideas for solving that problem, and then test those solutions, using what designers have done to inform later designs (Yilmaz, Paepcke-Hjeltness, & Dhadphale, 2016). Design thinking is human-centered, empathetic, and systemic, focusing on visualization, teamwork, and multiple solutions for the same problem (Yilmaz et al., 2016). In the context of computer, electrical, and software engineering, design thinking contrasts with the typical engineering design process: where the typical process is linear and focused on applying math and science; design thinking is expansive in its consideration of users, resources, and multiple solutions.

Understanding how students in specific engineering disciplines comprehend and develop engineering identities is important for efforts that seek to disrupt inequitable conditions within engineering and increase representation for historically marginalized groups in higher education and professional practice. This qualitative case study utilized data from the computer, electrical, and software (CES) engineering undergraduate students at a public research university in the Midwest to answer the following research question:

- What is the influence of design thinking pedagogy on undergraduate students' CES engineering identities?

Literature Review

Design thinking is important to engineering identity development because it encourages engineers to consider their work's impacts in a holistic way (Schweitzer, Groeger, & Sobel, 2016). Rather than focusing solely on the requisite skills needed for a project, design thinking fosters creative problem solving, empathetic thought, and collaboration to flourish within innovation (Liu & Lu, 2014). The iterative nature of design thinking encourages a theory-to-practice mindset (Johansson-Skoldberg, Woodilla, & Cetinkaya, 2013), influencing how engineers develop their own engineering identity. However, there is a need to understand better how design thinking affects students' engineering identity development from both subordinated and majority social identity categories.

Identity Development and Engineering Identity Development

Identity development is well-researched in higher education literature (Cross & Paretti, 2012; Patton, Renn, Guido-DiBrito, & Quaye, 2016). Studies of this kind help faculty, student affairs practitioners, and administrators better understand the students they serve, create interventions that support learning and challenges for growth, and ultimately help students succeed in college. Further, a growing body of literature has focused on the development of STEM identities for college students (Carlone & Johnson, 2007; Galczynski, 2016; Godwin, 2016; Rodriguez & Lehman, 2017; Rodriguez, Lu & Bartlett, 2018). Engineering disciplines typically identify as producers of both people and ideas who can meet the needs of an ever-changing world (Rippon, Collofello, & Hammond, 2012). To meet this need, it stands to reason that students need to successfully develop an engineering identity as part of their academic pursuits (Chachra, Kilgore, Loshbaugh, McCain, &Chen, 2008; Pierrakos, Beam, Constanz, Hohri, & Anderson, 2009).

Engineering identity should not be conceived of a destination or a simple, idealized goal. Instead, it is a continuous and reflexive process that students must navigate over time. That ultimately allows them to self-author (Baxter Magolda, 2008; 2014) an engineering identity that "fits" and is comfortable (Cross & Paretti, 2012; Godwin, Potvin, Hazari, & Lock, 2013; Pozzer & Jackson, 2015; Stevens, O'Connor, & Garrison, 2005). Pozzer and Jackson (2015) explicitly highlighted the tension among researchers who study engineering identity, stating, "Some researchers view identity as something individuals possess, while others consider identity as existing only in and through interactions, thereby being constantly renegotiated" (p. 213). Breaking away from one-dimensional conceptions of identity development allows for the consideration that multiple intersecting identities respond to the environments and contexts in which people find themselves (Abes, Jones, & McEwen, 2007; Pierrakos, et al., 2009).

Furthermore, thinking of engineering identity beyond simple self-categorization ("I am an engineer" or "I am not an engineer yet") signifies that there is influence on the development of engineering identity ("They are an engineer like me" or "He doesn't have what it takes to be an engineer") (Chachra, et al, 2008; Cross & Paretti, 2012; Godwin et al., 2013; Pierrakos et al., 2009). Gascyzynski (2016) noted that students are likely to feel both internal and external pressures while developing an engineering identity; the development journey is unique to the individual, and therefore difficult to generalize. We agree with Pozzer and Jackson (2015) that identity should not be understood solely as a self-categorization (a "possession") but as an interactive "negotiation" with contextual realities.

Although scholarship on engineering identity development is varied, available models underscore that engineering identity development is multi-dimensional and evolutionary. Sociologists connect this research with the foundational work of Stryker (1968), who wrote on the importance of symbolic interactionism and role identity theory. Stryker wrote that "behavior is the product of a role-making process, initiated by expectations but developing through a subtle, tentative, probing interchange among actors in given situations that continually reshapes both the form and the content of the interaction" (p. 559). Although there are several models, we draw on the work of Godwin and colleagues (2013, 2016), who identified three engineering identity constructs: 1) interest, 2) performance/competence, and 3) recognition. Students need to be aware of and interested in engineering, have the skills to do the work successfully, and be recognized by peers as "one of the group" in some fashion. In 2016, Godwin presented a model to measure these three constructs using quantitative methods, with over 2500 first-year engineering students reaffirmed the previous findings with her colleagues. All this is to say: engineering identity does not simply "happen," but develops over time, and the study of engineering identity development is multi-dimensional.

Marginalized Experiences in Engineering Education

Although research indicates that engineering identity development is iterative, it also shows that this process is not equitable for all people. Scholars cite the difficulty engineering academic programs have had in recent years in recruiting *and* retaining students, particularly women and students of racially or ethnically minoritized groups (Cross & Peretti, 2012). Leaving problems that "cannot be ignored and are of significant concern" (Pierrakos et al., 2009, p. M4F-1). Changing U.S. demographics have outpaced the representation of diverse populations in the engineering and STEM workforce. Although engineering education programs have attempted to increase the structural diversity of women students and those of color to rectify this concern, representation has not significantly changed in recent years (Cross & Peretti, 2012; Diekman, Brown, Johnston, & Clark, 2010; Hug, Jurow, & Chi, 2011; Knight et al., 2013). Knight and colleagues' research suggested that ethnicity plays an important role in developing an engineering identity. At the same time, Chachra's and her team's (2008) study of first- and third-year students indicated that participants differ by gender on what they consider to be the most crucial engineering activities (what engineers *do*). Women participants in the study also indicated that they felt disrespected and underestimated compared to men and were more likely to experience academic burnout. Pierrakos et al. further add, "With engineering being among the least gender-equitable and race-equitable professions in the United States, great strides must be made to improve enrollment and diversity in engineering" (p. M4F-1). Adding to the concerns about race and gender, Hughes (2017) studied the limited sense of belonging of gay graduate and undergraduate students in engineering based on hegemonic masculinity and LGBT people's erasure in diversity efforts. By studying the impacts of social identity on engineering identity development, researchers can create interventions that eliminate the engineering academic environment's harmful effects that hinder retention and persistence.

Engineering Identity Development for *All*

Studying engineering identity development among college students is a worthy endeavor, as increasingly noted (Rodriguez et al., 2018), but studies that do not account for the influences of social identities (such as race, gender, sexual orientation) are incomplete. Research can better prepare academic programs to meet the demands of an understaffed workforce that is predominantly White and predominantly male. Literature mentioned thus far indicates that the more a person's engineering identity is fostered—through interest, confidence, belonging, interactions, and commitment—the more likely a person is to succeed in their academic work (Godwin, 2016; Godwin et al., 2013; Pierrakos et al., 2009; Rodriguez, Cunningham, & Jordan, 2017). The more engineering education can validate historically minoritized persons as engineers, the higher their persistence to a degree will be (Chachra et al., 2008; Diekman et al., 2010; Pierrakos et al., 2009).

As the literature bears out, engineering identity is important, supporting its development for college students in a healthy way via the curriculum and other structural factors (Meyers, Ohland, Pawley, Silliman, & Smith, 2012). Furthermore, studying the various engineering sub-disciplines (e.g., computer, electrical, mechanical, etc.) is important (Rodriguez & Lehman, 2017). The efficacy of possible interventions, such as design thinking, needs to be assessed on a disciplinary level.

Design Thinking

Given that engineering fields continue to evolve (Channell, 2018) to fit a more technologically connected world and that engineering has a long history of providing solutions to technical and social problems, it is important to begin thinking about how to prepare engineers to think about issues holistically in the college classroom. Design thinking may be one solution that allows engineers to think about critical issues from all angles and connects them to the human impact of their work. Design thinking, when it comes to engineering, can be described as a process of thinking about current and future engineering issues holistically and allowing for the adaptation of professional skill sets (Schweitzer, Groeger, & Sobel, 2016). Design thinking can be used in any science. The engineering field helps engineers connect with more empathic elements, such as anticipated customer needs and cost-effectiveness. Empathic design (Kouprie & Visser, 2009; Leonard & Rayport, 1997) involves being able to meet the needs of your customers, getting to know what is important to them, and perhaps designing something they need before they realize they need it. With design thinking, engineers can incorporate new skills and integrate creative confidence (Rauth, Koppen, Jobst, & Meinel, 2010). Creative confidence considers a human and a sustainability-centered approach, the ability to use language as a tool, and the importance of working with others in a team (Razzouk & Shute, 2012). Design thinking in the college classroom may help practice engineers incorporate innovation forms to solve social issues (Liu & Lu, 2014).

As engineering students go through higher education, expectations to understand safety, customer needs, ingenuity, and concepts like sustainability are critical to the learning process (Stouffer, Russell, & Oliva, 2004). Utilizing design thinking or "designerly thinking" (Johansson-Skoldberg, Woodilla, & Cetinkaya, 2013, p. 123), meaning the linkage of theory to practice, may help students begin to think about how engineering work affects real people. Prior scholarship has shown that design thinking can be brought into the classroom through design thinking courses (Dunne & Martin, 2006; Liu & Lu, 2014). Such courses would consider the interactions between instructors and students, students and peers, and students and social issues or problems (Liu & Lu, 2014). Providing students with an opportunity to work in teams would allow them to ask additional questions, connect their learning, and make their learning experience interdisciplinary (Fry, 2006). Likewise, working in teams encourages students to take on the responsibility to iterate questions back and forth and find solutions before consulting with an instructor (Liu & Lu, 2014). Working in teams could also help engineering students draw on different individual skills and areas of knowledge. By finding connections between courses and learning from their peers, engineering students could use skills learned from other science areas to influence the work they complete in engineering (Dym, Agogino, Eris, Frey, & Leifer 2005).

Design thinking offers engineers an opportunity to look at many sides of an issue by taking a more holistic approach. Also, it allows engineers to think about the people they affect with their products more empathetically. Using empathy in design thinking can help engineering students think about the communities they will affect with their work and the values, skills, and areas of academic strength they bring into the classroom and eventually into the engineering profession. Because design thinking allows engineers to be more empathetic, a design thinking course could provide early engineers with an opportunity to make their learning interdisciplinary and think about their connections to and identity in their chosen field.

Theoretical Framework

Our study is grounded in Gee's (2001) discussion of role identity theory and engineering education research on engineering identity dimensions. Gee (2001) characterizes identity as "being recognized as a certain 'kind of person'" (p. 99). The conditions in which this recognition occurs may change depending on what identity is being recognized (e.g., gender 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 many ways, and who and how a particular identity is recognized is crucial (Gee, 2001). In this way, engineering identity depends on the individual and how they understand themselves and others—peers, instructors, and institutions—to recognize them as engineers.

As discussed above, engineering education researchers have developed an engineering identity (Godwin, 2016; Godwin et al., 2013). Many early constructs focused on performance and or competence—if a student was competent in math, science, and engineering courses, they were more likely to develop an engineering identity (Godwin, 2016; Godwin et al., 2013). However, researchers have since found that performance and competence need to be supplemented by additional constructs of interest and recognition for a more accurate understanding of engineering identity (Carlone & Johnson, 2007; Godwin, 2016). While performance and competence remain important, students must also be interested in engineering and be recognized as an engineering person—in other words, to believe that engineering is for them and have that belief validated by others (Godwin et al., 2013).

In addition to role identity theory, the present study utilized tenets of intersectionality (Collins, 1986; Crenshaw, 1991) to understand how multiple, intersecting identities (e.g. gender, race, ethnicity, SES), and, therefore, multiple forces of oppression influence how engineering students with marginalized identities experienced their learning environments. For this paper's purposes, we conceptualize those with dominant engineering identities as participants who identify as White, Asian, and or men who have historically been well-represented in the computer, electrical, and software (CES) engineering fields. In contrast, we conceptualize those with marginalized engineering identities as having identities or backgrounds that have been historically marginalized by these fields (e.g., women, people of color, first-generation college students). Intersectionality allowed us to understand how students of various identities were systematically included or marginalized from CES engineering spaces and how design thinking had on their perceptions and interactions.

Method

This research study utilized a qualitative case study approach (Merriam, 1998) to understand the influence of design thinking pedagogy on undergraduate students' CES engineering identities at a Midwest public research university with a full college of engineering and a historically focused STEM fields. This study is part of a multi-study, five-year project funded by the National Science Foundation (NSF). This grant aims to redesign required, middle-years courses in a CES engineering department in order to a) enhance students' professional development as empathetic, human-centered engineers and b) change the culture of the department to make it more student-centered and inclusive. Among the case study methodology's hallmarks are collecting data within a bounded system (Merriam, 1998). In this study, we narrowed our inquiry not only on undergraduate students within a particular institution, as referenced above, but we also focused on students enrolled in specific electrical engineering courses, described below. In keeping with Merriam's (1998) outline of a case study's components, the researchers utilized student questionnaires, interviews, observations, and document review to understand the impact of design thinking pedagogy on engineering identity development in undergraduate students.

Student Questionnaire & Interviews

Interview participants met the following criteria: (a) were over the age of 18, (b) majoring in CES engineering, and (c) were enrolled in one of two courses currently undergoing redesign: a second-year electrical engineering course called "Circuits" or a second-year computer engineering course called "Embedded Systems." While each course involves a design project, students in Embedded Systems received various instruction forms about design thinking. For example, in one course, students participated in a design thinking workshop at the beginning of the fall semester. In contrast, design thinking was introduced as part of the final project in the spring semester. Participants were recruited through several avenues: flyers hung in labs and engineering buildings, emails sent by course instructors on behalf of the researchers; information posted by instructors on course websites; and announcements made by researchers in classes and labs.

Participants (n=21) were electrical (11), computer (8), and software (2) engineering majors. The majority (16) was classified as juniors or seniors and was under age 25. Thirteen identified as men, while seven identified as women (one participant did not respond). Most identified as White (10) or Asian (8); one identified as Black/African American (one preferred not to answer, another did not respond). Participants included five community college transfer students, five international students, and one first-generation college student. Reported family income levels vary.

This study utilized a pre-interview questionnaire to gather demographic and background information (e.g., major, GPA, gender, parent education level). Data received enabled the researchers to create a greater understanding of the student participant profile for the group and identify aspects of a student's experience that might need to be explored during the interview. After the questionnaire, each participant participated in a one-hour, semi-structured interview. Individual interviews allowed the researcher to delve more deeply into the participant's experience with design-thinking and engineering identity. Interview questions explored personal definitions of engineering practice, interests, self-assessments of engineering performance/competence, and recognition feelings. Special attention was paid to how redesigned design thinking courses influenced students' understanding of their own engineering identities. Interviews were conducted face-to-face at a mutually agreed upon location and were recorded and transcribed for later analysis.

Observations

To further understand the influence of design thinking pedagogy on engineering identity, the researchers also engaged in lecture- and laboratory-based observation of the Circuits and Embedded Systems classes. Embedded Systems were observed for two semesters (Fall 2017/Spring 2018), while Circuits were observed during one semester (Spring 2018). The researchers engaged in 83 hours of observation in design thinking and non-design-thinking lectures and laboratory settings across ten sections of the courses. Observations can be characterized as participant-observation; however, researchers engaged in minimal participation in classroom lectures and laboratory activities. At times, the researchers observed sections where the interview participants were enrolled, but this was not part of the study's design (students sometimes attended lab sections other than their own). All observations were documented in field notes, utilizing an observation protocol derived from Spradley (1980). The protocol focused on concepts from the theoretical framework (e.g., performance, competence, interest, recognition, identity, intersectionality) and allowed them to understand the disciplinary context described in participants' interviews.

Document Review

Examining existing public-facing and internal documents enabled the researchers to understand the influence of design thinking pedagogy on engineering identity within the present research site context. Documents provided an understanding of engineering students' experiences in the departmental and university context. Public-facing documents included outreach information on the university website about the department and the three majors, transfer plans from state community colleges, graduation/curricular requirements, and study plans. Internal documents included self-study reports for each of the three programs. Some documents blurred the lines between public and internal, such as the college and department strategic plans. The study included only documents produced within the last five years, ensuring that they reflected current departmental life.

Data Analysis & Trustworthiness

All data sources were analyzed using concepts from the study's theoretical framework to understand the influence of design thinking pedagogy on undergraduate students' CES engineering identities within these specific classes' bounded systems on one university campus. We utilized Dedoose, data analysis software, to systematically code, analyze, and conduct reports across multiple data sources. Public and internal-facing documents and observation data were analyzed first, followed by the pre-interview questionnaires and interview transcripts. We utilized *a priori* codes drawn from our conceptual framework (e.g., performance, competence, interest, recognition, identity, and intersectionality) in our first round of coding. We also engaged in emergent coding as certain patterns emerged from the data inductively during the open coding process, such as our observations about marginalized students noted in the findings section. We then engaged in the second round of coding that enabled us to develop inductive observations axially across data sources while further incorporating the theoretical framework. Throughout this process, each of the five coders recorded emerging patterns in memos, which were shared and discussed by the full group at several meetings during the analytical process. We discussed our impressions of the data and patterns noticed and resolved disagreements or differences in interpretation at these meetings. Memos included reports of patterns and data drawn from the sources to provide evidence of those patterns, which we then used as the foundation for each of the findings that we discuss below.

To ensure trustworthiness, the researchers met regularly at each stage of the project to discuss findings and discuss differences in interpretation. They also kept a research log and codebook that served as an audit trail for the data collection and analysis processes. Because this study is part of a larger project focused on engineering identity development for CES engineering, the researchers periodically debriefed other educational researchers and engineering colleagues. They also explored their positionalities and potential biases. As all of the researchers came from the School of Education at the institution where the study was conducted, none of them held insider perspectives as either engineering students (past or present) or researchers in that college. Three research team members have studied STEM issues relating to the identity or have professional experience advising and supporting undergraduate students in STEM fields. Lastly, we share some identities that have framed our experiences, including being women (4 authors), being lesbian, bisexual, gay, transgender, queer (LBGTQ+) (2 authors), and being Latina (3 authors). The study's researchers held various insider and outsider positionalities, which enabled them to understand and contextualize the findings and identify actionable recommendations for institutions. In addition, their differing starting points allowed participants' experiences to be examined, interpreted, and discussed in a variety of ways.

Findings

In this section, we articulate our findings, which have three primary themes. First, its design thinking pedagogy enhances engineering identity development. Second, in particular, design thinking influences engineering identity development among marginalized students. Within this second theme, three sub-themes emerged, which provided nuance to marginalized students' interests, performance, and outcomes. Finally, we learned that the process of implementing design thinking pedagogy is crucial.

Design Thinking Pedagogy Enhances Engineering Identity

Design thinking pedagogy enhanced engineering identity through its ability to connect students with real-life simulation design activities that encouraged them to not only acquire technical competence but also recognize themselves in their role as engineers. For example, Colin said that the design opportunities embedded within the course built their sense of engineering identity. They welcomed further opportunities to use design thinking in their classes: "There's going to be a lot of design opportunities there, and those are going to help me feel like an engineer 'cause you have to draw from what you know to meet certain specifications they lay out for you." Students connected design thinking concepts, such as pursuing incremental but persistent progress, engineering identity, and their future work. Notably, Nicholas, a white man, described building a solar car as an incremental cycle of teaching and mentoring among his classmates: "There are people on that team that know a lot more than I do, so a lot of the time it's them teaching me. And then I'll teach the people under me." This process was not just helpful in getting through classes, as this student explicated further, but also prepared him for the profession: "It's nice, because that's how you learn how real engineering works. It's not just solving problems on paper; it's actually solving real world problems."

Design thinking does not guarantee the development of an engineering identity, however. In their interviews, students often expressed reluctance to claim engineering identities, refer to themselves as engineers, or connect the curriculum to post-graduation engineering work. They expressed frustration that what they were learning in the classroom and lab often did not align with solving real-world problems. Within a design thinking-enhanced course, Priscilla (a South Asian woman) recounted a moment of particular frustration when taking an exam. She described having to go through a data sheet of over a thousand pages to answer the questions on the exam while her computer was not loading the data fast enough for her to do so. She said, "I was really frustrated because it felt like I wasn't tested on the concepts…In the real work, I'll have time to think about what exactly I'm doing." In short, this exam represented a disconnect between course expectations and the actual work students would be asked to do as engineers, post-graduation.

Some students felt that design thinking was dissonant with the broader curriculum at the university. Many students in this study chose this specific university because of its reputation as a top engineering school. However, they also pointed out that the school's reputation created pressure to perform, often without human aspects like empathy and creativity. Students described their engineering experiences as a series of rote learning practices that focused on building specific technical skills and allowed little freedom for design or creative thinking. Students felt that they had little control over their educational experiences and felt that the university was trying to create a specific type of engineer with a particular type of engineering identity. Speaking of the lack of proper design thinking elements in engineering in general, Ashley, a white woman, stated, "When I think of the stereotypical engineering mold, everything…is linear from day one. Like, you think of binary, which is ones and zeros or Black and White—that is exactly what our department is like." Commenting on the effects of these expectations, she said, "Our students don't have empathy. And so if you aren't able to perform at high levels of success consistently without fail like…a machine would, it almost feels like you don't belong here."

Demanding course loads of perceived irrelevant material perpetuated students' idea as "survivors" of the curriculum, rather than learners building an engineering identity. Omar, a man from the Middle East, discussed his interaction with industrial design majors. He recalled several of them saying, "Hey, I was an engineer, but I couldn't do it. It's just too many classes, too [much] work for me." The student observed these industrial design students' work, which he described as "just spectacular," and concluded, "I guess, in a sense, we [engineering majors] are the best survivors." This was echoed in Colin's (an East Asian person who presented as a man, but did not identify his gender) interview where they described persistence as a crucial characteristic for an engineering student: "If you give up easily…that's one way you know for sure you're not an engineering person."

The Importance of Design Thinking and Engineering Identity for Marginalized Students

Within this study, there was a strong connection between design thinking and engineering identity, particularly as it nurtured engineering interests and allowed opportunities for marginalized students to reframe what it means to be an engineer. In all, 12 out of the 21 participants in this study came from identities that were in one way or another marginalized in engineering or higher education writ large. These included identifying as a woman, a student of color, an international student, a first-generation student, or a non-traditional student (e.g., a transfer student, a veteran student, etc.). We noted that participants from these backgrounds processed the design thinking curriculum differently than those from the populations more traditionally represented within engineering (e.g., males from White and or Asian backgrounds). In short, students from marginalized backgrounds felt that design thinking enabled them to feel more connected to engineering disciplines since they were able to incorporate their interests and visualize themselves in an engineering role.

Design Thinking Nurtures Engineering Interests. Whereas much of the engineering curriculum seemed to sometimes discourage creativity, empathy, and application, students with marginalized identities said design thinking projects encouraged them to sustain their interest in engineering and design thinking pedagogy enhanced their feeling of being potential engineers. Amanda, an Asian woman, majoring in electrical engineering, said, “I think it is incredibly valuable to put a story or some sort of thought into how something you’re creating is being used.” In contrasting her views with others, she stated, “I think a lot of engineers really like concept projects or things they just want to make something work or they’re very willing to just be given a task and then do.” Students articulated how design thinking mindsets and activities encouraged them to see their engineering coursework as a non-linear, human-centered process, making them feel more connected to the curriculum. In the laboratory, students engaged with CES alumni working as computer, electrical, and software engineers in various industries who could give guidance on students’ research projects. The design thinking approach provided opportunities for real-world applications of their ideas, and the outside visitors provided feedback and validation that their projects mirrored engineers’ activities. Alexandra (a white woman) explained, “I like [the real-world application] because we’re actually seeing where someone who actually uses this, how they would use it, and things like that.” Through design thinking, students were able to conceptualize engineering as a function of continuous progress, despite setbacks, and to improve the world around them.

Design Thinking Allows Opportunities for Engineering Identity Performance. Design thinking pedagogy also allowed students to create more positive team dynamics and enabled them to perform their engineering identities and be recognized by their faculty, teaching assistants, and peers. Researchers observed several ways design thinking pedagogy was actualized in the lab setting. For example, faculty members answered questions in ways that offered opportunities to demonstrate competence by inviting questioners to walk them through a possible solution or process. They also used various rhetorical strategies to acknowledge competence, such as mentioning which information the students already knew and what course they learned it in rather than saying that they should know or might remember it. TAs guided students through the lab and, when most successful, encouraging an open atmosphere for asking questions, working through mistakes, and connecting their interests with the material. TAs establish norms in engineering, telling students what to do and praising them for certain behaviors. Peers can provide recognition of skills and opportunities to share competence.

Design thinking allowed students to reframe how they saw the role of engineers (e.g., worker versus humanitarian), and activated a sense of altruism that inspired students to see themselves as engineers working for the public good. Omar, an international student from the Middle East, spoke at length about returning to his home country post-graduation to use his degree to improve lives there. While other students (especially the majority of students) may have talked about technical innovation, Omar defined the heart of engineer thus: “They look for problems that a lot of people might not know or know and to find solutions taking a lot of things into consideration and kind of helping other people.” Omar valued the knowledge and skills gained through his degree program for their beneficial applications.

Design Thinking Engineering Identity Experiences Differed for Majority Students. On the other hand, most White and Asian male participants in this study did not describe design thinking or design thinking aspects (e.g., creativity, empathy) as an engineer’s characteristics. The majority of men did not appear to give their engineering identities much consideration. Instead, they demonstrated such confidence in their engineering capabilities that, while they may have questioned *what kind* of engineer they were, they rarely questioned *if they belonged* in engineering. For instance, Logan, a White man, discussed his father’s influence as an engineer himself and his high school classes, especially a formative passion for math and science. He arrived at the university with a strong proclivity toward engineering. As such, his most significant decision was deciding whether to be a mechanical or electrical engineering major. Benjamin, a White man, described a similar natural affinity for engineering, and when asked what being an engineer meant to him, simply stated, “I guess you could define it as if your title says engineering, but also if you’re in any sort of role that creates something.” For Benjamin, being an engineer was explicitly tied to having a job where that was part of the job title.

Differences in gendered participation were particularly striking. We noted that women interacted with their classmates much differently within the observation data than men, primarily White men. One field note memo asked in a lecture observation, “Why aren’t female students asking questions?” After this first observation, this researcher continued to notice that women and men participated differently. Throughout the semester, women were remarkably silent in class—they not only often speak often during lectures, but also rarely spoke to each other. In observations of common study spaces, observers also noticed that women tended to either study together or not study in group settings at all.

This absence from public participation was better contextualized by the interview data. For example, Priscilla, a South Asian woman who was highly engaged with many aspects of the program (e.g., NSF-funded projects, student groups) and who was selected for multiple internships over her academic career, described assumptions that she felt male classmates made about her despite her accomplishments: "It seems like I'm being judged a bit. Do I actually do my labs? Am I getting it from other people, all that kind of stuff." The result was that Priscilla tended to purposely isolate herself from male classmates, especially in the common study space within the engineering building, even though she exhibited confidence in her capabilities as an engineer. These tensions between students' perceptions of themselves as engineers and how they felt their peers perceived them complicated the implementation of the design thinking curriculum, particularly in promoting teamwork and collaboration.

The Approach to Implementation of Design Thinking Pedagogy was Essential

Overall, findings also demonstrated that the process of implementation of design thinking pedagogy was essential to ensuring positive outcomes for engineering identity, especially for historically marginalized students. It was successfully embedding design thinking elements into the curriculum required that students understood the purpose of introducing these ideas and felt a sense of coherence across the classroom and laboratory activities and the larger curriculum. Amanda, who spoke with the most enthusiasm about design thinking, happened to be taking an additional independent study while taking the redesigned course. She admitted that she saw "a lot more value in design thinking than a lot of [her] peers do" as a result of the independent study. Talking specifically about the redesigned course, she argued that it "definitely [has] kinks to be worked out because it's its first year being introduced into the program, but I see a lot of value in it." When well-integrated, students could articulate the value in design thinking and connect these concepts to what it means to be an engineer. Implementation practices that focused on explaining design thinking concepts, articulating its purpose, and demonstrating its value encouraged students to view the course redesign more positively.

Poor implementation discouraged participants from responding to activities and taking advantage of design thinking opportunities to enhance engineering identity. Students expressed concern about the placement of design thinking concepts in the curriculum. They said design thinking did not belong in this particular course or that it should have been introduced earlier in the curriculum for greater alignment. Study participants were all at different levels in their degree programs, including some who were in their final year who said the design thinking content came too late for it to be effective. Students reiterated the need both for class and curriculum alignment with design thinking. Priscilla (Asian woman) called for greater integration of design thinking within the course to emphasize its importance:

> they're trying to implement this thing called engineering thinking, which I mean I do appreciate …I think it's important to talk about, but the way it's placed in [the redesigned course], it's just random. It's just like thrown in there…I feel like design thinking isn't adequately included.

Along similar lines, Amanda (Asian woman) believed that if design thinking "were introduced earlier in the program and more integrated into the program then it's something that would, in the long run, benefit the entire department." Compounding this challenge, a common thread throughout the interviews was how demanding and time-intensive pursuing an engineering degree is. The design thinking component could seem like an extra requirement in an already crowded curriculum. As Corey (a White man) put it, "My cup was already full, it's hard to add more water."

Simultaneously, students perceived a lack of organization in the course redesign and admitted to often not understanding how design thinking fits with the more technical course content. Rather than augmenting the course design, some students perceived a re-designed curriculum as meaning merely more assignments. Students described being "lost" or completing assignments "in the dark" with little guidance. Jacob, a community college transfer student, related that professors should help students make connections across the curriculum to enhance design thinking:

> I think the big thing is helping them see the connection…you can start to build the connection yourself; but I think sometimes a little guidance towards the connection and how it would be applied, really helps, cause it, for me personally, really helps me really understand what's going on, so now I understand how to apply it to questions in the real world.

Students also felt frustrated by the course's pace and the number of assignments that did not lend themselves to a meaningful design thinking process. Omar talked about the many weekly hours he spent reading and studying for class. Omar described how rather than enabling creative alternative solutions to the problems posed in class and labs or giving students time to figure them out, "the professors usually give examples of how to do things or procedures of how to do things, and we are being expected to know that instead of [playing] around and [messing] around or [asking] questions."

As a result, students, particularly those from dominant identities (i.e., White and or men), developed a sense of separation between the technical aspects of engineering and the design thinking process. Students saw tasks labeled "design thinking" as distracting from the "real work" (i.e., technical work) of engineers, thus creating disconnects between engineering and the design thinking process. As Chad (a White man) criticized, "This is already a busy enough class where we're already…trying to grapple with how to make a board, how to write code to do a thing." To add more reflective design thinking elements was a "loosey-goosey" approach, Chad found needless when the technical aspects of the course already taught students what they needed to know. Therefore, for students like Chad, design thinking did not complement or enhance their technical engineering process. Interestingly, when asked if he could describe "design thinking," Nicholas referred to the technical design that goes into building anything and referenced a wooden train he built in high school. When asked to describe what being an engineer meant to him, Nicholas echoed some design thinking concepts to improve society through technical innovation. However, he did not connect them with design thinking.

Despite integrating design thinking concepts, engineering students remained disconnected from their learning experiences. Observations demonstrated that even in design thinking redesigned lectures, students continued to sleep, surf the internet, a slump in their chairs, and lack a sense of presence in the class. Lectures continued to take a "sage-on-the-stage" approach and seemed to discourage student interest in engineering, with many students being disengaged in the learning process. Lectures did not often allow time or opportunity to be recognized as an engineer or to perform one's identity as an engineer. The labs allowed for more of this kind of activity. Labs were highly unstructured and seeming a bit chaotic. Students lost interest, became frustrated, or resorted to one person doing the group's work as time went on. The researchers consistently observed students doing various off-assignment tasks, including eating lunch, checking their email, shopping online, and doing homework for other courses. Throughout the semester, lab hours were dedicated time and space for groups to develop their semester-long projects. As part of the project, students were required to think of a backstory for their embedded system, its purpose, its application, and to think about who would benefit from it. Although labs more easily lent themselves to design thinking activities in integrating group work with a human-centered purpose, these activities did not appear to be aligned clearly with traditional design thinking processes or the lecture content.

Summary of Findings

By using concepts of role theory and intersectionality, our findings indicate that design thinking positively impacts engineering identity development for computer, electrical, and software engineering students, though it is not necessarily guaranteed. For marginalized students, in particular, we found that design thinking fosters engineering interests and performance. Nevertheless, the findings also paint a more complex picture by also revealing the limitations of design thinking pedagogy. Notably, the limitations flow from faculty members' ability to incorporate design thinking into the learning environment in ways that resonate with students.

Discussion

This paper—part of a larger research project centered on design thinking, engineering identity, and professional formation—explores the impact that design thinking pedagogy may have on the undergraduate computer, electrical, and software engineering. Although it was difficult at times to isolate design thinking's impact from the general pressure and strain of coursework, the findings indicate that when implemented correctly, design thinking can be beneficial for engineering identity development and maintenance. However, that positive impact can be inhibited by problems in implementation or by ignoring the intersection of social identities with design thinking in engineering spaces.

This research extends previous work by connecting design thinking not only to engineering work but also to engineering identity. We found that design thinking can enhance undergraduate engineering identity by helping students make connections between engineering coursework and real-world applications, providing structure for positive team dynamics and group work, and supporting the development of empathy. The gains students found in professional skills, such as teamwork, empathy, and problem-solving, mirror the benefits previous research has found in design thinking for engineers (Rauth et al., 2010; Razzouk & Shute, 2012; Schweitzer et al., 2016). Additionally, this research highlights the role that teaching assistants and peers can have in shaping design thinking pedagogy and engineering identity experiences. Working in teams and with peers has been shown to help students become dynamic problem-solvers, find connections between different courses and experiences, and take responsibility for learning (Dym et al., 2005; Liu & Lu, 2014). The students in this study often focused on the teamwork aspect of design thinking, highlighting the critical role their teams played in their engineering experiences and their engineering identity development.

Juxtaposed to the benefits presented by design thinking is our finding that the intentional implementation of design thinking was essential in determining whether it would help or hurt students. Indeed, design thinking pedagogy often did both. The students we interviewed did not see connections between the technical content of their courses and the design thinking interventions, which was exacerbated by the location of design thinking in the lab context. In addition to feeling like more work piled onto an already heavy course, the design thinking process and its lack of incorporation into the course and the broader curriculum confused and frustrated students. Therefore, this study extends the current research on design thinking by being frank about design thinking's potential pitfalls if the implementation is not undertaken carefully. Since design thinking is sometimes rhetorically thought of as existing in opposition to engineering (especially in students' minds), instructors and programs need to carefully implement this pedagogy throughout the entire engineering curriculum rather than in one or two technical content or design project courses.

We also found that students with historically marginalized identities experienced developing their engineering identities and design thinking differently than their more traditionally represented counterparts. While some engineering fields have more balanced numbers of women and students of color, electrical, computer, and software engineering are still predominantly White and predominantly male (Lord, Layton, & Ohland, 2011). This reality was visually evident to us as researchers (many of whom are women and some of whom are Latina) as we continually found lecture halls and labs peopled mostly by men and White men. Understanding the experiences of these historically marginalized students represents the intersection between two large bodies of research: identity development in college writ large (Cross & Paretti, 2012; Patton et al., 2016) and engineering identity research (Godwin, 2016; Godwin et al., 2013; Pierrakos et al., 2009; Pozzer & Jackson, 2015). In other words, we are capturing students' experiences not only developing engineering identities but doing so in the context of broader identity development, which includes racial and gendered—and other—identities.

We found that students from historically marginalized backgrounds develop engineering identities differently from the design thinking curriculum than students from majority backgrounds. Students from historically marginalized backgrounds could make their electrical and computer engineering coursework more relevant to their own lives and priorities, thus bringing more meaning to their studies. These students became more able to visualize themselves as engineers—something that men, mainly, were already able to do. Often, White and male students viewed design thinking as a distraction, representing skills and dispositions they did not see as part of engineering identity. While many participants maintained that gaining credentials in the form of a college degree signaled achievement of "engineer," design thinking pedagogy allowed some to imagine themselves as engineers already, despite opposition and doubt from their peers. Research has found that viewing oneself as an engineer supports persistence and retention (Brickhouse, Lowery, & Shultz, 2000; Carlone & Johnson, 2007; Pierrakos et al., 2009). Therefore, design thinking, when well-implemented, could materially contribute to increasing diversity and equity in CES.

Limitations

There are limitations to this study that may affect its applicability. First, due to the nature of the larger study, this used one-time interviews as opposed to a longitudinal design. Thus, we are limited to capturing student engineering identities in a single moment rather than tracking their longer-term development. Additionally, students were interviewed at different times in each semester of data collection, meaning that they may have had more or less exposure to design thinking in comparison to their peers. Finally, design thinking was implemented each semester differently, and in each course. While implementation decisions were largely outside of the researchers' control, they may have affected how participants thought about their engineering identity, design work in general, and design thinking specifically.

Implications for Research & Practice

This study suggests that design thinking is a fruitful area to explore to create more inclusive engineering environments. Future research should consider a longitudinal design; identity development does not occur in one class or even one semester—it is a perpetual process that takes place throughout undergraduate education and professional practice. Therefore, capturing the effect of design thinking across a broad span of time would be illuminating. Future research should also narrow its focus on historically marginalized identities. While the purpose of this broader project was to consider design thinking's general impact on engineering identity, additional studies should focus specifically on historically marginalized students in a variety of engineering contexts, including different institutional types (PWIs vs. MSIs, for example) or different engineering fields, or should focus on specific groups, such as international students, students of color, or students with multiple and intersecting identities (such as Black women engineering students). Finally, our study accounts only for the student perspective. Future research should consider a 360-degree view that includes faculty and teaching assistants' perspectives as they implement design thinking pedagogy to gain a fuller picture of the process and intended outcomes for student engineering identities.

This study's findings will assist educational stakeholders in understanding the design thinking pedagogy and engineering identity experiences of CES undergraduate engineering majors. Findings may encourage institutions to view the engineering curriculum in terms of identity development and understand how intersectional identities influence the ways students, particularly those from marginalized backgrounds, experience the environment. Stakeholders will be able to enhance classroom pedagogies, encourage identity development, and, ultimately, improve undergraduate persistence outcomes in engineering. This is particularly important as higher education explores ways to make engineering more diverse and reconstruct environments to eliminate marginalization forms.

In terms of pedagogical practice, we found that even small doses of design thinking can enliven computer, electrical, and software engineering courses. However, this implementation must be both intentional and broad. Design thinking needs to be included across the curriculum, rather than concentrated in one or two courses. Additionally, it is important to consider the different ways—influenced by their backgrounds and multiple and or intersectional identities—that students and faculty approach design thinking. Design thinking cannot be applied wholesale without considering who the target population is and what the desired outcomes are. Similarly, although we recommend that engineering departments consider implementing design thinking as a beneficial practice, it is not a cure-all for everything. Design thinking should be implemented alongside other learning tasks that encourage empathy, ethical behavior, and professionalism.

Conclusion

This study found that design thinking, when well-implemented, can have a positive effect on undergraduate engineering identities. This effect may be incredibly impactful for students from historically marginalized groups because design thinking allows them to connect engineering coursework to their lives. While individuals from dominant groups were often able to assume an engineering identity by virtue of declaring major, marginalized students looked to elements of the curriculum to reinforce their role as an engineer. Continuous enhancement of engineering pedagogy, through concepts such as design thinking, may encourage students to see themselves in the role of an engineer and successfully transition to the workforce.

References

Abes, E. S., Jones, S. R., & McEwen, M. K. (2007). Reconceptualizing the model of multiple dimensions of identity: The role of meaning-making capacity in the construction of multiple identities. *Journal of College Student Development, 48*(1), 1-22. https://doi.org/10.1353/csd.2007.0000

Baxter Magolda, M. B. (2008). Three elements of self-authorship. *Journal of College Student Development, 49*(4), 269-284. https://doi.org/10.1353/csd.0.0016

Baxter Magolda, M. B. (2014). Self-authorship. *New Directions for Higher Education, 166*, 25-33.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37*(5), 441-458.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching, 44*(8), 1187-1218.

Chachra, D., Kilgore, D., Loshbaugh, H., McCain, J., & Chen, H. (2008, June). *Being and becoming: Gender and identity formation of engineering students*. Paper presented at the meeting of the American Society for Engineering Education, Pittsburgh, PA.

Channell, D. F. (2018). *The Rise of engineering science: How technology became specific.* Richardson, Texas: Springer International Publishing.

Collins, P. H. (1986). Learning from the outsider within: The sociological significance of black feminist thought. *Social Problems, 33*(6), 14-32.

Crenshaw, K. W. (1991). Mapping the margins: Intersectionality, identity politics, and violence against women of color. *Stanford Law Review, 43*(6), 1241-1299.

Cross, K. J., & Paretti, M. C. (2012, June). *Identification with academics and multiple identities: Combining theoretical frameworks to better understand the experiences of minority engineering students*. Paper presented at the American Society for Engineering Education, San Antonio, TX.

Diekman, A. B., Brown, E. R., Johnston, A. M., & Clark, E. K. (2010). Seeking congruity between goals and roles: A new look at why women opt out of science, technology, engineering, and mathematics careers. *Psychological Science, 21*(8), 1051-1057.

Du, X-Y. (2006). Gendered practices of constructing an engineering identity in a problem-based learning environment. *European Journal of Engineering Education, 31*(1), 35-42.

Dunne, D., & Martin, R. (2006). Design thinking and how it will change management education: An interview and discussion. *Academy of Management Learning & Education*, *5*(4), 512-523.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching, and learning. *Journal of Engineering Education*, *94*(1), 103-120.

Foor, C. E., Walden, S. E., & Trytten, D. A. (2007). “I wish that I belonged more in this whole engineering group": Achieving individual diversity. *Journal of Engineering Education, 96*(2), 103-115.

Fry, R. (2006, June). *Understanding "design thinking" in the context of education*. Paper presented at the meeting of the American Society for Engineering Education, Chicago, Illinois.

Galczynski, M. (2016, June). *Exploring the impact of engineering student and professor expectations on the development of student engineering identity and navigation.* Paper presented at the meeting of the American Society for Engineering Education, New Orleans, LA.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research in Education, 25*, 99-125.

Geisinger, B. N., & Raman, D. R. (2013). Why they leave: Understanding student attrition from engineering majors. *International Journal of Engineering Education*, *29*(4), 914–925.

Godwin, A. (2016). *The development of a measure of engineering identity*. Paper presented at the meeting of the American Society for Engineering Education, New Orleans, LA.

Godwin, A., Potvin, G., Hazari, Z., & Lock, R. (2013). Understanding engineering identity through structural equation modeling. *2013 IEEE Frontiers in Education Conference (FIE)*. Oklahoma City, OK.

Hug, S., Jurow, A. S., & Chi, W. C. (2011). *Evolving identities: Undergraduate women pursuing the engineering professoriate*. Paper presented at the meeting of the American Society for Engineering Education, Vancouver, BC, Canada.

Hughes, B. E. (2017). “Managing by not managing”: How gay engineering students manage sexual orientation identity. *Journal of College Student Development, 58*(3), 385-401

Johansson-Sköldberg, U., Woodilla, J., & Çetinkaya, M. (2013). Design thinking: past, present and possible futures. *Creativity and innovation management*, *22*(2), 121-146.

Knight, D., Sullivan, J. F., Kotys-Schwartz, D. A., Myers, B. A., Louie, B., Luftig, J. T.,…Hornback, J. M. (2013, June). *The impact of inclusive excellence programs on the development of engineering identity among first-year underrepresented students*. Paper presented at the meeting of American Society for Engineering Education, Atlanta, GA.

Kouprie, M. & Sleeswijk Visser, F. (2009). A framework for empathy in design: Stepping into and out of the user's life. *Journal of Engineering Design, 20*(5), 437-448.

Liu, A. & Lu, S. Y. (2014, June). *Reinforcing a ”design thinking” course by restructuring student-instructor interactions*. Paper presented at the meeting of American Society for Engineering Education, Indianapolis, IN.

Leonard, D., & Rayport, J. F. (1997). Spark innovation through empathic design. *Harvard Business Review, 75*, 102-115.

Lord, S. M., Layton, R. A., & Ohland, M. A. (2011). Trajectories of electrical engineering and computer engineering students by race and gender. *IEEE Transactions on Education, 54*(4), 610-618.

Luka, I. (2014). Design thinking in pedagogy. *Journal of Education Culture and Society, 2*, 63-74.

Merriam, S. (1998). *Qualitative research and case study applications in education*. San Francisco, CA: Jossey-Bass.

Meyer, M., & Marx, S. (2014). Engineering dropouts: A qualitative examination of why undergraduates leave engineering. *Journal of Engineering Education, 103*(4), 525-548.

Meyers, K. L., Ohland, M. W., Pawley, A. L. Silliman, S. E., & Smith, K. A. (2012). Factors relating to engineering identity. *Global Journal of Engineering Education*, 14(1), 119-131.

Patton, L. D., Renn, K. A., Guido-DiBrito, F., & Quaye, S. J. (2016). *Student development in college: Theory, research, and practice* (3rd ed.). San Francisco, CA: Jossey-Bass

Pierrakos, O., Beam, T. K., Constantz, J., Johri, A., & Anderson, R. (2009). *On the development of a professional identity: Engineering persisters vs engineering switchers*. Paper presented at the meeting of the American Society for Engineering Education, Austin, TX.

Pozzer, L. L., & Jackson, P. A. (2015). Conceptualizing identity in science education research: Theoretical and methodological issues. In C. Milne, K. Tobin, & D. DeGonnaro (Eds.), *Sociocultural Studies and Implications for Science Education* (pp. 213-230). Dortrecht, Netherlands: Springer. DOI: https://doi-org.proxy.lib.iastate.edu/10.1007/978-94-007-4240-6.

Rauth, I., Köppen, E., Jobst, B., & Meinel, C. (2010). Design thinking: An educational model towards creative confidence. In *DS 66-2: Proceedings of the 1st international conference on design creativity (ICDC 2010)*.

Razzouk, R., & Shute, V. (2012). What is design thinking and why is it important? *Review of Educational Research, 82*(3), 330-248.

Rippon, S., Collofello, J., & Hammond, R. R. (2012, June). *"OMG! That's what an engineer does?": Freshmen developing a personal identity as an engineer*. Paper presented at the meeting of the American Society of Engineering Education, San Antonio, TX.

Rodriguez, S. L., Cunningham, K., & Jordan, A. (2017). STEM identity development for Latinas: The role of self- and outside recognition. *Journal of Hispanic Higher Education*. DOI: 10.1177/1538192717739958

Rodriguez, S. L., & Lehman, K. (2017). Developing the next generation of diverse computer scientists: the need for enhanced, intersectional computing identity theory. *Computer Science Education, 27*(3-4), 229-247.

Rodriguez, S. L., Lu, C., & Bartlett, M. (2018). Engineering identity development: A review of the higher education literature. *International Journal of Education in Mathematics, Science and Technology, 6*(3), 254-265.

Schweitzer, J., Groeger, L., & Sobel, L. (2016). The Design Thinking Mindset: An Assessment of What We Know and What We See in Practice. *Journal of Design, Business & Society, 2*(1), 71-94.

Shanahan, M-C. (2009). Identity in science learning: Exploring the attention given to agency and structure in studies of identity. *Studies in Science Education, 45*(1), 43-64.

Spradley, J. (1980). *Participant observation*. New York, NY: HBJ College Publishers.

Stevens, R., O'Connor, K., & Garrison, L. (2005, June). *Engineering student identities in the navigation of the undergraduate curriculum*. Paper presented at the meeting of the American Society of Engineering Education, Portland, OR.

Stouffer, W. B., Russell, J. S., & Oliva, M. G. (2004). Making the strange familiar: Creativity and the future of engineering education. In *Proceedings of the 2004 American Society for Engineering Education Annual Conference & Exposition* (Vol. 9, pp. 1-9).

Stryker, S. (1968). Identity salience and role performance: The relevance of symbolic interaction theory for family research. *Journal of Marriage and Family, 30*(4), 558-564.

Yilmaz, S., Paepcke-Hjeltness, V., & Dhadphale, T. (2016). *The Nature of Design Thinking in Academia and Industry*. Design Research Society: Brighton.

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