

Inclusion & Marginalization: How Perceptions of Design Thinking Pedagogy Influence
Computer, Electrical, and Software Engineering Identity¹

Sarah Rodriguez
Iowa State University

Erin Doran
Iowa State University

Rachel E. Friedensen
St. Cloud State University

Elizabeth Martínez-Podolsky
Iowa State University

Paul S. Hengesteg
Iowa State University

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Abstract

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 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 important foundation to foster student interest in the course and connection to their role as an engineer.

Key Words: Identity; STEM; engineering; design thinking, inclusion

Developing and maintaining an engineering identity plays a key role in the educational experiences of undergraduates 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 the development of their engineering identities (Du, 2006; Foor, Walden, & Trytten, 2007; Hughes, 2017). These challenges and barriers are the result of structural inequities, but are often internalized by students and expressed as problems with themselves rather than with the field (Carlone & Johnson, 2007; Shanahan, 2009).

Engineering identity is not fully clear to researchers, and there is little consensus about which interventions are successful in helping students develop engineering identities. 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 has been done previously to inform later designs (Yilmaz, Paepcke-Hjeltness, & Dhadphale, 2016). Design thinking is human-centered, empathetic, and systemic, and focuses 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 is placed in contrast to the typical engineering design process: where the typical process is linear and focused on applying math and science to a problem, 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 as well as professional practice. This qualitative case study utilized data from 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

Engineering is everywhere. Historic and modern advances – ranging from the construction of the pyramids to the building of bridges and skyscrapers to the invention and utilization of the computer to having homes with clean running water and electricity – are all connected to the work of engineers. Our global civilization's reliance on engineers has not diminished with time (in fact, just the opposite), and higher education institutions are wise to offer academic programs that appropriately develop engineers prepared to meet future challenges as we progress through the twenty-first century..

Identity Development and Engineering Identity Development

Identity development is well-researched in higher education literature (Cross & Parette, 2012; Patton, Renn, Guido-DiBrito, & Quayle, 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 a holistic way 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, 2018; Rodriguez, Lu & Bartlett, 2018). Engineering

disciplines have been identified as the 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 a professional 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. Rather, it is a continuous and reflexive process that students must navigate over time that ultimately allows them to self-author (Baxter Magolda, 2008; 2014) themselves into an engineering identity in a way that “fits” and is comfortable (Cross & Parette, 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 a person finds 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 others influence engineering identity development (“They are an engineer like me” or “He doesn’t have what it takes to be an engineer”) (Chachra, et al, 2008; Cross & Parette, 2012; Godwin et al., 2013; Pierrakos et al., 2009). Gasczynski (2016) reiterated that students are likely to feel both internal and external pressures as they develop 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 thought of solely as a self-categorization (a “possession”) in favor of an interactive “negotiation” with contextual realities.

Although scholarship varies on the components of engineering identity development, two popular models underscore the fact that engineering identity development is multi-dimensional and evolutionary. Undergirding these studies, sociologists will connect this research with the foundational work of Stryker (1968) who wrote on the importance of symbolic interactionism and role identity theory. Stryker says 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) Pierrakos and colleagues (2009) suggested that engineering identity is developed in college students in four areas: 1) knowledge of the profession and exposure to engineering, 2) interest in engineering and influences to enter the major, 3) sense of preparedness, and 4) sense of belonging, fit, and commitment. Although these researchers indicated a limited sample for their study and therefore cautioned against generalizability, their work suggests that the more a student feels the positive effects of, or connected to, any one of these four areas, the more likely they are to persist through the degree successfully. On the other hand, the work of Godwin and colleagues (2013, 2016) refined the previous study to identify three engineering identity constructs: 1) interest, 2) performance/competence, and 3) recognition.

When comparing the two studies, logical commonalities are found. Students need to be aware of and interested in engineering, have the skills to be able to do the work successfully and satisfactorily, and need to also be recognized by peers as “one of the group” in some fashion. In 2016, Godwin presented on her development of a model to measure these three constructs using quantitative methods with over 2500 first-year engineering students, thereby reaffirming the

previous findings with her colleagues. All this is to say: engineering identity does not simply “happen,” it is developed 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, research 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, in particular 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 demographics of the U.S. population 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 in order 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 the development of a professional engineering identity while Chachra’s team’s (2008) study of first- and third-year students indicated that participants differ by gender on what they consider to be the most important activities of engineering (what engineers *do*). Women participants in the study also indicated that they felt disrespected and underestimated as compared to men, and are 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 realities of race and gender, Hughes (2017) supplements the body of literature by studying the limited sense of belonging of gay graduate and undergraduate students in engineering based on hegemonic masculinity and the erasure of LGBT people in diversity efforts. By studying the impacts of social identity on the development of professional engineering identity development, researchers are able to create interventions that reverse the negative effects of the engineering academic environment that cause retention and persistence concerns.

Engineering Identity Development for *All*

The study of engineering identity development among college students is a worthy endeavor for scholars as noted by its increased presence in literature (Rodriguez et al., 2018), but studies that are not also cognizant of the influences of social identities (such as race, gender, sexual orientation) are incomplete. Such research will 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 professional engineering identity is fostered – through interest, confidence, belonging, interactions, and commitment – the more successful that student is likely to be 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 persistence to degree will be (Chachra et al., 2008; Diekman et al., 2010; Pierrakos et al., 2009).

As the literature bares out, engineering identity is important, and supporting the development of that identity for college students in a healthy way via the curriculum and other structural factors is important (Meyers, Ohland, Pawley, Silliman, & Smith, 2012). Furthermore, studying the various sub-disciplines (e.g., computer, electrical, mechanical, etc.) of engineering

is important (Rodriguez & Lehman, 2018). The efficacy of possible interventions, such as design thinking, needs to be assessed on a disciplinary level.

Design Thinking

As engineering fields continue to evolve (Channell, 2018) to fit a more technologically connected world, it is crucial to understand how to best address current issues through engineering. Given that engineering has a long history of providing solutions to technical and social problems, it is important to begin thinking about how we are teaching engineering and preparing engineers to think about issues holistically in the college classroom. Design thinking may be one solution through which engineers can meet future societal needs as it allows them the opportunity to think about critical issues from all angles and connects engineers to the human impact that their work makes.

Design thinking, when it comes to engineering, can be described as a thinking process about current and future engineering issues holistically and allow for the adaptation of their professional skill sets (Schweitzer, Groeger, & Sobel, 2016). Although design thinking can be used in any science, when used in engineering it helps engineers connect with more empathic elements, such as anticipated customer needs and cost effectiveness. Empathic design (Kouprie & Visser, 2009; Leonard & Rayport, 1997) speaks to being able to meet the needs of your customer, getting to know what is important to them, and perhaps designing something the customer needs before they realize they need that product. With design thinking, engineers can look to incorporate new skills and integrate creative confidence (Rauth, Koppen, Jobst, & Meinel, 2010). Creative confidence within engineering takes into account a human and sustainably-centered approach, the ability to use language as a tool, and the importance of working with others in a team (Razzouk & Shute, 2012). Likewise, design thinking in the college classroom may be a solution to getting practicing engineers to incorporate new ways of innovation for solving social issues (Liu & Lu, 2014).

As engineering students go through higher education, expectations to understand safety, customer needs, ingenuity, and integrating concepts like sustainability are critical to the learning process (Stouffer, Russell, & Oliva, 2004). Given that most engineering education is evolving to meet current needs, 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 a design thinking course (Dunne & Martin, 2006; Liu & Lu, 2014). Design thinking courses would consider the interactions between instructors and students, students with their peers, and students with the social issue or problem (Liu & Lu, 2014). By providing students with an opportunity to work in teams, design thinking students could ask additional questions, connect their learning, and make their learning experience interdisciplinary (Fry, 2006). Likewise, working in teams encourages students to take on some of the responsibility to reiterate questions back and forth and find solutions before consulting with instructor (Liu & Lu, 2014). Working in teams could also help engineering students as it draws on different individual skills and areas of knowledge. By finding connections between courses and learning from their peers, engineering students could essentially use some of the skills learned from other areas of science to influence the work they complete in engineering (Dym, Agogino, Eris, Frey, & Leifer 2005).

Design thinking is an opportunity for engineers to look at the many sides of an issue by taking more of a holistic approach. In addition, design thinking allows engineers and scientists to think about the population of people they are affecting with their products by being more empathic. Using empathy in design thinking can assist engineering students by thinking about the communities they will affect with their work, but more importantly, what values, skills, and areas of scholarly strength they bring into the classroom and eventually into the engineering profession. Because design thinking allows engineers to be more empathic, perhaps a design thinking course in college could provide early engineers with an opportunity to make their learning interdisciplinary and get students to think about their own connections and identity to their chosen field.

Theoretical Framework

Our study is grounded in Gee's (2001) discussion of role identity theory as well as engineering education research on the dimensions of engineering identity. 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 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 on others—peers, instructors, and institutions—to recognize them as an engineer.

As discussed above, engineering education researchers have developed measures of 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 valid understanding of engineering identity (Carlone & Johnson, 2007; Godwin, 2016). While performance and competence remain important, students must also be interested in CES engineering and be recognized as an engineering person—in other words, students need 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 research study utilized tenets of intersectionality (Collins, 1986; Crenshaw, 1991) in order to understand how multiple, intersecting identities (e.g. gender, race, ethnicity, SES), and, therefore, multiple forces of oppression, influence the way in which engineering students with marginalized identities experienced their learning environments. For the purposes of this paper, we conceptualize those with dominant engineering identities as participants who identify as White, Asian, and/or men who have historically been well-represented in computer, electrical, and software engineering fields. In contrast, we conceptualize those with marginalized engineering identities as participants who identify as having identities or backgrounds which have been historically marginalized by these fields (e.g. women, people of color, first-generation college student). Intersectionality allowed us to understand how students along various lines of identity were systematically included or marginalized from CES engineering spaces and the influence that design thinking had on those perceptions and interactions.

Methods

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 robust college of engineering and a historical focus on STEM fields. This study is part of a multi-study, five-year project funded by the National Science Foundation (NSF). The aim of this grant is to redesign required, middle-years courses in a CES engineering department in order to a) enhance students' professional development into empathetic, human-centered engineers and b) change the culture of the department to make it more student-centered and inclusive. In keeping with Merriam's (1998) outline of the components of a case study, the researchers utilized student questionnaires, interviews, observations, and document review in order 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 currently 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 forms of instruction about design thinking. For example, students in one course participated in a design thinking workshop at the beginning of the fall semester, while design thinking was introduced as part of the final project in the spring semester.

Participants were electrical (11), computer (8), and software (2) engineering majors. The majority (16) of participants were classified as juniors or seniors and were under age 25. Thirteen of the participants identified as men while seven identified as women (one participant did not respond to the question). Most participants identified as White (10) or Asian (8); one participant 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 ranged. Table 1 provides more detail on interview participants.

This study utilized a pre-interview questionnaire in order 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 as well as identify aspects of a student's experience that might need to be explored during the interview. After the questionnaire, each participant (21 total) 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 feelings of recognition. Special attention was paid to how redesigned design thinking courses influenced their 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 data analysis.

Observations

In order to further understand the influence of design thinking pedagogy on engineering identity, researchers also engaged in lecture- and laboratory-based observation of the Circuits and Embedded Systems classes. The Embedded Systems course was observed over the course of two semesters (Fall 2017/Spring 2018), while the Circuits class was 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. The researchers engaged in minimal participation in classroom lecture and laboratory activities. All observations were documented in the form of field notes, utilizing an observation protocol (derived from Spradley, 1980). The observation protocol focused on concepts from the theoretical framework (e.g. performance, competence, interest, recognition, identity, intersectionality) and allowed the researchers to understand the disciplinary context which participants described in their interviews.

Document Review

Examining existing public-facing and internal documents enabled researchers to understand the influence of design thinking pedagogy on engineering identity within the present research site context. Documents allowed researchers to understand the experiences of engineering students within 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 plans of study. 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 documents, which were produced within the last five years, ensuring that we were using documents that reflect 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. We utilized Dedoose, a data analysis software, to allow researchers to systematically code, analyze, and conduct reports across multiple data sources. Public and internal-facing documents and observation data were analyzed first in order to provide context for understanding the pre-interview questionnaires and interview transcripts. Each data source was read several times and electronically coded (initial open coding, followed by a more detailed codebook coding) for concepts related to the theoretical framework (e.g. performance, competence, interest, recognition, identity, intersectionality). From this coding, significant patterns within the data were noted and possible explanations and propositions for the findings were proposed.

To ensure trustworthiness, the researchers met regularly at each stage of the project to discuss findings and discuss differences in interpretations. Researchers 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, researchers also periodically debriefed findings with other educational researchers and engineering colleagues. Furthermore, the researchers also engaged in exploring their own positionalities and potential biases. The study's researchers held a variety of insider and outsider positionalities which enabled the researchers to understand and contextualize the findings of this study in order to identify actionable recommendations for institutions. In addition, these differing starting points allowed for the experiences of participants to be examined, interpreted, and discussed in a variety of ways.

Findings

Design Thinking Pedagogy Enhances Engineering Identity

Design thinking concepts contrasted with the greater engineering environment present 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 which 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 as if the university was trying to create a certain type of engineer with a particular type of engineering identity. Speaking of the lack of true design thinking elements in the engineering field in general, Ashley, a white woman, stated, "When I think of the stereotypical engineering mold, everything in engineering 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 went on to say, "Our students don't have empathy. And so if you aren't able to perform at high levels of success consistently without fail like how a machine would, it almost feels like you don't belong here."

Demanding course loads of perceived irrelevant material perpetuated the idea of students as "survivors" of the curriculum, rather than learners building an engineering identity. Omar, a male student from the Middle East, discussed his interaction with industrial design majors, and 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 he concluded, "I guess, in a sense, we [engineering majors] are the best survivors." This was echoed in Colin's (an East Asian man) interview where he described persistence as a crucial characteristic for an engineering student: "If you give up easily, I think that's one way you know for sure you're not an engineering person."

Within their interviews, students often felt reluctant to claim their engineering identities, refer to themselves as engineers, or connect the curriculum to post-graduation engineering work. They felt a sense of frustration that what they were often learning in the classroom and lab did not align to solving real-world problems. Within a design thinking-enhanced course, Priscilla (a South Asian woman) recounted a moment of particular frustration when she was taking an exam. She described having to go through a data sheet of over a thousand pages to answer the questions on the exam and having issues where her computer was not loading the data fast enough for her to answer the questions. In reflecting on the exam, 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 professional engineers post-graduation.

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 to recognize themselves in their role as engineers. Colin, for example, said that the design opportunities embedded within the course built their sense of engineering identity, and 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 the pursuit of incremental but persistent progress, as connected to 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 to getting through classes, as this student explicated further, but design thinking and interactions with classmates also prepared him for the profession as he went on to say, “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.”

Marginalized Identities Influence Engineering Identity

In all, 12 out of the 21 students who participated in this study came from identities that are in one way or another marginalized in the engineering field or in the system of higher education writ large. These identities include 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 more traditionally represented populations 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 own personal interests and visualize themselves within the engineering role.

Whereas much of the engineering curriculum discouraged creativity, empathy, and application, students with marginalized identities felt as if design thinking projects encouraged them to sustain their interest in engineering. In contrast, design thinking pedagogy enhanced the way in which students, particularly those with marginalized identities, felt like 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 which made them feel more connected to the curriculum. As part of their laboratory hours, students engaged with CES alumni who now work as professional computer, electrical, and software engineers in a variety of industries who could give guidance on students’ research projects. The design thinking approach gave students a real world application of their ideas, and the outside visitors provided feedback and validation that their projects mirrored the activities students would complete as professionals. As Alexandra (a white woman) explained, “I like that [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 persistent progress, despite setbacks, and a means for them to improve the world around them.

Design thinking pedagogy also allowed students to create more positive team dynamics and enabled in students the ability 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 often offered opportunities for performance of competence and recognition by students by inviting the questioner to walk them through a possible solution or process. They both also used various rhetorical strategies to acknowledge student competence—for example, they would often mention which information the students already knew and what course they learned it in rather than saying that they should know it or they might remember it. TAs guide students through the lab and, when most successful, encourage an open atmosphere for students to ask questions, work through mistakes, and connect their interests with the material. TAs establish

given norms in engineering, telling students what to do and praising students for certain behaviors. Peers can provide recognition of skills and give opportunities for a student to share their competence with a topic.

For instance, design thinking allowed students to reframe the ways in which they see the role of engineers (e.g. worker versus humanitarian), and, in many ways, activated a sense of altruism that inspired students to see themselves as engineers working for a public good. Omar, an international student from the Middle East, spoke at length about returning to his home country post-graduation in order to use his degree to improve the lives of people there. While other students (especially majority students) may have talked about technical innovation, Omar defined the heart of engineer in this way: “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.” Throughout this interview, it seemed that the knowledge and skills Student 1 gained throughout his degree program was useless to him unless he could find beneficial applications to them.

On the other hand, we found that most of the White and Asian male participants in this study felt that design thinking or some of the design thinking aspects (e.g., creativity, empathy) were not characteristics of an engineer. In fact, majority males 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 the engineering profession. For instance, Logan, a White man, discussed his father’s influence as an engineer himself and his high school classes, especially a love for math and science, as formative for him arriving at the university with a strong proclivity toward engineering. As such, his biggest decision was deciding whether he wanted to be a mechanical or electrical engineering major. Benjamin, a white man, described a similar natural affinity to engineering, and when asked what being an engineer meant to him, this student 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 specifically tied to having a job where that was a specific part of the job title.

Differences in gendered participation were particularly striking. Within the observation data, we noted that women interacted with their classmates much differently than men, especially White men. Within a lecture observation, one field note memo questioned, “Why aren’t female students asking questions?” After this first observation, this researcher continued to notice that women and men participated differently. Throughout this semester of observations, it was clear that women were remarkably silent in class—they not only did not speak often during lectures, they also rarely spoke to each other. In observations of common study spaces, observers also noticed that women tended to either study together or did 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, students groups) and who was selected for multiple internships over her academic career, described many of the 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 of these feelings is that this student tended to purposefully isolate herself away from male classmates, especially in the common study space within the engineering building, even though she exhibited confidence in herself about 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.

Implementation of Design Thinking Pedagogy was Essential

Overall, findings also demonstrated that the implementation of design thinking pedagogy was essential to ensuring positive outcomes for engineering identity, especially so for historically marginalized students. 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 as well as the larger engineering curriculum. Amanda, who spoke with the most enthusiasm about design thinking, happened to be taking an additional independent study at the same time she was 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. When talking specifically about the redesigned course, she argued the course "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. It just needs to be ironed out." When well-integrated, students were able to 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 in a more positive light.

Poor implementation discouraged participants from responding to activities and taking advantage of design thinking opportunities to enhance engineering identity. Students expressed concern about placement of design thinking concepts in the curriculum. They felt as though it did not belong in this particular course or that it should have been introduced earlier in the curriculum for greater alignment. The students who participated in this study were all at different places in their degree programs, including some students who were in their final year where they felt like the design thinking content came too late for it to be effective. Compounding this challenge, a common thread throughout the interviews was how demanding and time-intensive pursuing an engineering degree is. When it came to the design thinking component, students felt like it was an extra requirement on top of an already crowded curriculum. As Corey (a white man) put it, "My cup was already full, it's hard to add more water it... The labs are already jam-packed with technical information. To try to add another piece to it, it didn't all fit."

At the same time, students perceived a lack of organization in the course redesign implementation and admitted to, at many times, not understanding how design thinking fit within the rest of the more technical course content. Rather than augmenting the design of the course, some students felt as though a re-designed curriculum simply meant more assignments for them. Students felt as though they were "lost" or completing assignments "in the dark" with little guidance about the process. Students felt frustrated by the pace of the course and the amount of assignments which did not lend themselves to a meaningful design thinking process. Omar talked about the tremendous number of hours per week he spent reading and studying for class. Rather than learning about creative alternative solutions to the problems posed in class and labs or giving students time to figure out their own solutions to a problem, Omar described how "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 felt as though tasks labeled “design thinking” were distracting from the “real work” (i.e. technical work) of engineers, thus creating disconnects between what they perceived as engineering and the design thinking process. As Chad (a white man) criticized, “This is already a busy enough class where we’re already like 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 to Chad that was needless when he felt the technical aspects of the course already taught students what they needed to know for future. Students even created a distinction between engineering identity and design identity to further separate these concepts. Interestingly, when asked if he could describe “design thinking,” Nicholas referred to the technical design that goes into building anything and he referenced the parts of a wooden train he built in high school. When asked to describe what being an engineer means to him, Nicholas echoed some of the concepts of design thinking in terms of finding ways to improve society through technical innovation, but he did not connect these ideas with design thinking.

Despite integrating design thinking concepts, engineering students remained disconnected from their learning experiences, leading one of the authors to write in a reflective memo, “I wish there was an apathy code.” Observations demonstrated that, even in design thinking redesigned lectures, students continued to sleep, surf the internet, slump down 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 be able to perform one’s identity as an engineer. Labs allowed for more of this kind of activity. Labs are highly unstructured times, seeming a bit chaotic, and, as the time period goes on, students lose interest, get frustrated, or resort to one person doing the work for the group. The researchers consistently observed students doing a variety of off-assignment tasks, including eating lunch, checking their email, shopping online, and doing homework for other courses. Throughout the semester, the 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 back story for their embedded system, its purpose and application, as well as to think about who would benefit from their project. 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

Using concepts of role theory and intersectionality, this study showed that design thinking provides opportunities to enhance engineering identity, particularly for students with marginalized identities. For students with marginalized identities, design thinking encouraged students to express sustain their interest and see themselves in the role of an engineer. As such, thoughtful implementation of design thinking concepts is essential to creating and sustaining student interest in computer, electrical, and software engineering.

Discussion

This paper—part of a larger research project centered on design thinking, engineering identity, and professional formation—set out to explore the impact that design thinking pedagogy may have on 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 do indicate that when done correctly, design thinking can be beneficial for engineering identity development and maintenance. However, that positive impact can be

mitigated 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 these 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, rather than faculty members, can have on shaping design thinking pedagogy and engineering identity experiences. Working in teams and with peers has been shown to help students become more 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 important role that their teams played both in their engineering experiences and in the development of their engineering identity.

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 the students in our study—indeed, design thinking pedagogy often did both. The students we interviewed had a sense of disconnect between the technical content of their courses and the design thinking interventions, a feeling that was exacerbated by the location of design thinking within the lab context. In addition to feeling like more work piled onto an already heavy course, students also felt confused by the design thinking process and frustrated by its lack of incorporation into both the course and the broader curriculum of the major. Therefore, this study actually extends the current research on design thinking by being frank about the potential pitfalls of design thinking if implementation is not carefully undertaken. Since design thinking is sometimes rhetorically thought of as existing in opposition to engineering (especially in the minds of students), instructors and programs need to implement this pedagogy carefully throughout the entire engineering curriculum, rather than in one or two technical content or siloed in design project courses.

We also found that students with historically marginalized identities experienced both the development of their engineering identities and design thinking differently than their more traditionally represented counterparts. While some fields of engineering have more balanced participation numbers for 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 obvious to us as researchers (many of whom are women and some of whom are Latina) as we continually entered lecture halls and labs to find them 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, 2013; Godwin et al., 2013; Pierrakos et al., 2009; Pozzer & Jackson, 2015). In other words, we are capturing the experiences of students not only developing engineering identities, but also 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 are developing engineering identities in relation to the design thinking curriculum differently than students from majority backgrounds. Students from historically marginalized backgrounds were able to make their electrical and computer engineering coursework more relevant to their own lives and priorities, thus bringing more meaning to their studies. These students were more able to visualize themselves as engineers—something that men, particularly, were already able to do. In many ways, white and male students viewed design thinking as a distraction, because it represented skills and dispositions that they did not see as part of engineering identity. While many students that we interviewed maintained that gaining credentials in the form of a college degree signaled achievement of the status of ‘engineer,’ design thinking pedagogy allowed some students to imagine themselves as engineers already, even in the face of 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, it is possible the design thinking, when well-implemented, could materially contribute to efforts to increase diversity and equity in computer, electrical, and software engineering.

Limitations

There are some limitations to this study that may affect its applicability. First, due to the nature of the larger study, these are one-time interviews as opposed to a longitudinal design. Thus, we are limited to capturing student engineering identities in a single moment rather than being able to track 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, there were different implementations of design thinking each semester and in each course. While implementation decisions were largely outside of the researchers’ control, they may have an effect on how the students interviewed thought about their engineering identity, design work in general, and design thinking specifically.

Implications for Research & Practice

Findings from this study suggest that design thinking is a fruitful area from which to explore ways to create more inclusive engineering environments. Future research should consider a longitudinal design, because identity development does not take place in one class or even in one semester—it is a perpetual process that takes place throughout undergraduate education as well as professional practice. Therefore, capturing the effect of design thinking across a broad span of time would be illuminating research. Future research should also narrow its focus on historically marginalized identities. While the purpose of this broader research project is 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 takes place only from the student perspective. Future research should consider doing a 360-degree view to include the perspectives of faculty and teaching assistants as they implement design thinking pedagogy to gain a fuller picture of both the process and their intended outcomes for student engineering identities.

The findings from this study 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 as a process of identity development and understand the way in which intersectional identities influence the way in which 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 for engineering students. This is particularly important as higher education explores ways to make engineering more diverse and reconstruct environments to eliminate forms of marginalization.

In terms of pedagogical practice, we found that even small doses of design thinking can enliven computer, electrical, and software engineering courses. Therefore, it is recommended to include elements of design thinking throughout the engineering curriculum. However, it is important that this implementation 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 can not 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 professional formation practice, design thinking 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 particularly impactful for the development of engineering identity for students from historically marginalized groups in engineering because design thinking allows them to connect engineering coursework in relevant ways to their lives. While individuals from dominant groups were often able to assume an engineering identity by virtue of declaring a 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 within the role of engineer and successfully transition to the workforce.

Table 1.
Participant Information

Name	Engineering Major	Year	CC Transf	Age	Race/Ethnicity	Gender	Int'l	1 st gen	Family Yearly Income
Omar	Electrical	Junior			Asian	Man	Y		
Amanda	Electrical	Junior		20	Asian	Woman			Unsure
Chad	Electrical	Senior		23	Prefer not to day	Man			Unsure
Mathieu	Computer	Junior	Y	21	Black or African American	Man	Y		\$70,000-\$79,000
Corey	Electrical	Junior		20	White/Caucasian	Man			\$100,000+
Andrew	Electrical	Senior		28	White/Caucasian	Man			Unsure
Vijay	Computer	Sophomore		19	Asian	Man			\$80,000-\$89,999
Jacob	Computer	Junior	Y	19	White/Caucasian	Man			\$100,000+
Logan	Electrical	Sophomore		20					Unsure
Nicholas	Electrical	Junior		20	White/Caucasian	Man			\$90,000-\$99,999
Joseph	Electrical	Junior	Y	20	White/Caucasian	Man			Unsure
Alisha	Computer	Sophomore		19	Asian	Woman			Unsure
Ajay	Computer	Other		21	Asian	Man	Y		Under \$19,000
Alexandra	Computer	Sophomore		19	White/Caucasian	Woman	Y		Unsure
Noah	Electrical	Junior		21	White/Caucasian	Man			\$30,000-\$39,999
Karen	Software	Senior		21	Asian	Woman	Y		Unsure
Amelia	Computer	Other	Y	19	White/Caucasian	Woman			Unsure
Colin	Electrical	Sophomore		19	Asian	Man			\$70,000-\$79,000
Ashley	Software	Junior	Y	20	White/Caucasian	Woman		Y	\$80,000-\$89,999
Priscilla	Computer	Junior		19	Asian	Woman			\$90,000-\$99,999
Benjamin	Electrical	Sophomore		19	White/Caucasian	Man			Unsure

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