

A Case Study: Making Facilitates an Engineering Student's (Re)Negotiation with Her Disciplinary Relationships

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Abstract

Marginalizing narratives in engineering (e.g. engineering is masculine, competitive, etc.) can significantly impact students' sense of belonging. Studies show that students shifting narratives about their relationships with engineering can support them in navigating the dynamics of marginalization. However, there is a lack of investigation into how engineering learning environments can be designed to facilitate students' (re)negotiation with these relationships. This work in progress presents a case study where Sarah, a second-year mechanical engineering student, (re)negotiated her relationships with engineering through a university course that focused on how people learn in different engagements with making. We draw from frameworks of practice-linked identity and history in person to understand how her relationships with engineering were influenced by the marginalizing narratives, how did the (re)negotiation happen, and how activities in the course supported her (re)negotiation. We discuss preliminary implications to inform how educators can use making to design learning environments that support engineering students' (re)negotiation with their disciplinary relationships.

Introduction

Despite the need for diversity in all forms (e.g. racial, gender, socioeconomic status, etc.) in engineering [1], marginalizing narratives still exist that affect individuals' participation in engineering. These narratives include: engineering is masculine and competitive [2], and engineering values technical competency much more than creativity and social interactions [1], [3], [4]. These narratives can lead to students feeling little sense of belonging, and their identities not being validated in engineering [5] [6]. Studies show that students shifting narratives about their relationships with engineering can support them in navigating the dynamics of marginalization [7]. However, there is a lack of investigation into how engineering learning environments can be designed to facilitate students' (re)negotiation with these relationships.

Making, defined by Sheridan *et al.* [8] as a process to develop an idea and construct it into some physical or digital form, can be a space for rich transdisciplinary engineering learning and practice [9] [10]. Making is a form of "heterogeneous engineering" [11] - engineering that emphasizes not only the technical aspect, but also the social, material, and political dynamics [12]. Making as heterogeneous engineering resists the marginalizing narratives that technology is the sole important aspect of engineering and that engineering can only be done by specific people that subscribe to masculinity. Therefore, making presents opportunities for them to challenge the dominant perspectives in engineering that are marginalizing. Making affords learners opportunities to relate to and see themselves in engineering work.

In this work in progress, we present the case of Sarah, an undergraduate student in mechanical engineering, whose relationship with engineering was once impacted by the marginalizing narratives. Yet, she (re)negotiated those relationships through a university course that provided her a space to reflect on her experiences in making and how those experiences contribute to her learning in engineering. Through this case study, we hope to provide insights into how educators can design learning environments using making to support engineering students to (re) negotiate their relationships with engineering. Our research questions include:

1. How did the activities in the course support Sarah's (re)negotiation of her relationships with engineering?
2. How can educators support engineering students' (re)negotiation of their disciplinary relationships?

Our plan is to first interpret the mechanisms of Sarah's shifting relationships with engineering and understand the role that making plays in the mechanism. Our second step is to zoom into detailed moments in the course where she made (re)negotiations to understand what components of making contributed to those (re)negotiations. Our third step is to conclude how we can use making to design learning environments that allow engineering students to (re)negotiate their relationships with engineering. We show the initial findings on the first step in this work in progress.

Conceptual framework

We use the framework *practice-linked identity* [13] to understand how Sarah perceives her identity in engineering, and *history in person* [14] to understand how Sarah's experiences related to making influence her identity in engineering.

Practice-linked identity

Learning and identity exploration go hand in hand [15]. Lave and Wenger [16] theorized the activity of learning as participating in communities of practitioners. As learners learn knowledge and skills, they are essentially moving towards full participation in the community, thus developing their identity in the community. In a university's engineering school, engineering student learns to participate in engineering practices so that eventually they become a full member of communities of engineers.

As learners develop new skills and construct new kinds of knowledge and practice, they also develop a sense of themselves entwined with the domain. Nasir and Hand [13] introduced "practice-linked identity" to describe how the sense of self (identity) is entwined with the practices of the community. For example, a student's practice-linked identity in engineering helps to describe how students connect with the practices of engineering. Practice-linked identity is a crucial element of one's learning because an individual is more engaged and learns more in a domain when they feel that their identity is linked to the settings [17] [18]. Therefore, college engineering students who feel a strong sense of connection between themselves and the activities they are asked to engage with in their coursework will likely experience a strong connection with

engineering; practice-linked identity offers a powerful lens through which to understand these dynamics.

To understand how learning environments can be designed to support students' development of practice-linked identity, Nasir and Hand [13] compared students' participation, learning, and engagement on basketball courts and in mathematics classrooms. They found that the basketball court supported students' development of strong practice-linked identity by encouraging them access to the domain of basketball, allowing them to play integral roles in the community, and providing opportunities for their self-expression so they can make unique contributions. In contrast, students were prevented from developing strong practice-linked identities in mathematics classrooms because they were positioned as followers not doers in the setting. Therefore, when designing learning environments, we should be mindful of what resources the setting affords students to develop practice-linked identities. Nasir and Cooks [19] identified these identity resources to be ideational, relational, and material resources. Ideational resources shape learners' sense of what is valued in the practice and how they shape their learning goals. Relational materials sustain learners' persistence through social interaction when they encounter hardship. Material resources are the artifacts and spaces that constitute the content of their learning.

Practice-linked identity illustrates how one's sense of belonging in a community is entangled with the activities and practices one participates in. Therefore, it helps us understand that Sarah's engagements with the practices within the engineering communities impact how she sees herself in engineering. We can also make sense of how her practice-linked identity changes based on which engineering community she participates in by looking into whether she feels connected to the practices of that community.

History in person

While the framework *practice-linked identity* suggests to us that Sarah's participation in the practices of a community influences her engagement and identity in the community, *history in person* helps us understand the mechanism of her (re)negotiation of her engineering identity - how does it happen and what contributes to it.

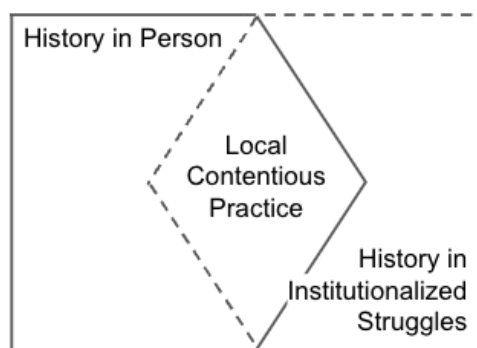


Figure 1: Relations between history in person and history in institutionalized struggles (Adapted from Holland and Lave, 2001, p. 7)

According to Holland and Lave [14], local contentious practice emerges from personal history and institutional history, as shown in figure 1. While the “practice” in “practice-linked identity” refers to activities within a community that involve two or more people [13], “practice” in “local

contentious practice” refers to the activity enacted by a person. A person enacts an activity (local contentious practice) based on both their own historical production (history in person) as well as the cultural-historical conjuncture of the institution (history in institutionalized struggles). Therefore, when one enters a new community, they take on the practices and ways of being they learned from other places in the past to adapt to the dynamic and narratives of the new community, so they can position themselves as a member of the community [20] [21].

This framework helps us understand the identity process of a new student entering engineering school. They figure out their position in the community by interpreting the narratives of engineering school and bringing in the previous experience that they see as relevant to the narratives. It also prompts us to think about the design of learning environments in engineering - to support students developing their identities in engineering, what are the institutionalized struggles presented in the environment and how does the environment afford students opportunities to bring in their history in person?

Methods

This study presents a case where Sarah, a second-year female mechanical engineering student, (re)explores and (re)negotiates her relationships with mechanical engineering through a course called “Making to Learn”.

Course of focus: Making to Learn

Making to Learn is a course offered at a medium-sized private university in New England. In spring 2022 when Sarah attended the course, the second author of this paper was the course instructor. The first author participated in the course as a “researcher-in-residence” - she attended all the sessions as a student, sometimes a TA that offered students technical help while collecting data at the same time. In the course, participants (students, the instructor, and the researcher-in-residence altogether) explore how one learns through making. We make various projects alone and together with others, all along reflecting on the practices and experiences of learning through making.

Building on designs developed in a STEM learning program by the second author [22], Making to Learn is organized around five making projects: restorying making, make something move, interaction, making do, and movements and improvements. The materials and tools presented to participants and the prompt for each project are listed in Table 1.

Participants also read research papers and articles that focus on important issues of equity in making and have regular discussions. They interrogated the narrative of “the maker movement” - while Dougherty [23] has been stressing that “everyone is a maker” in order to promote the maker movement, Make Magazine (the magazine that started from the maker movement) was still represented narrowly by projects made by White men [24]. They questioned how the popular “maker” culture believes that “people who make things are simply different [read: better] than those who don’t”, and is still a continuation of the technology culture that is situated in the male domain, centering productivity [25]. They explored the relationship between making and education through the lens of learning space design. Making can happen not only in an institutionalized “makerspace” in schools, or afterschool programs, but it also emerges naturally

Project name	Materials presented	Project prompt
Restorying making	Paper, razors	Work as individuals. Choose a picture that represents a form of making you engaged with before, then use paper weaving to recreate and tell the story.
Make something move	Craft materials such as card stock, mounting board, and wooden dowels	In a group, make something that contains mechanical movements.
Interaction	Same materials and tools from “make something move” alongside electronic tools such as Micro:bit, motors, and LEDs	In a group, make something that interacts, such as pop-up cards, responsive circuits, and dynamic sculptures, as well as art-making that asks someone to interact with a big idea.
Making do	Broken electronics such as old DVD players, remote controllers, camcorders, and tape recorders. Mechanical tools such as screwdrivers and hammers.	Work as individuals. Take apart broken electronics. Then construct the components to tell a story.
Movements and improvements	Participants are encouraged to use tools, materials, and processes that they know or want to learn.	Work as individuals or groups. Make projects that make your community a better place.

Table 1: Making projects in Making to Learn.

in students’ daily lives (e.g., households and garages). Making affords learning experiences that bridge the divide between formal and informal [26] [27].

After each making project, students were asked to submit a journal entry with prompts that guided them to reflect on what they learned in the project, and how are they thinking about making at that point. These reflective journals aimed to provide a space for students to explore and reflect on their relationship with making and learning, and how the making projects and readings affect their thinking.

Data sources

This study is based on data collected in Making to Learn, spring 2022. We collected data on all eight students that were in the course because all of them consented to participate in the study.

These eight students were in diverse stages in their academic pursuits, ranging from undergraduate freshmen to doctoral students. Their majors were a mix of Mechanical Engineering, Biology, Museum Education, Child Study and Human Development, and one student yet to declare. This study is situated in a larger study to analyze how making facilitates students' (re)negotiation with their disciplines across fields. We started our analysis with engineering students because both authors received a part of their higher education in engineering and are more familiar with the experience of engineering students. We developed our first case study around Sarah because she was the most vocal in her data regarding her shifting relationship with engineering.

These data include five reflective journals Sarah submitted throughout the course and two interviews with Sarah - before and after the course. The journals followed the prompts introduced in the previous section and present Sarah's reflective journey. The interviews were semi-structured. In both interviews, Sarah was asked about her making experiences and practices (e.g. What do you think making is? Can you describe an example of something you have made?) and relationship to engineering (e.g. How would you describe your relationship to your major? What do you think contributes to that relationship?). In the second interview, Sarah was asked to walk the first author through a project she made during the course, and to answer questions such as, "How did your relationship with your major and making change over the course?".

Analysis

We conduct a narrative inquiry [28] to develop a case study of Sarah. Initially, we open-coded [29] the data to identify analytical themes which include identity, materials and tools, personal experience with making, and relationship with engineering. Then we coded the data within each theme to explore recurring patterns.

Findings

In this work in progress, we present an initial analysis of Sarah's shifting relationships with engineering. We provide an analysis of how the narratives of engineering shaped how she interprets what is valued in the community and how that interpretation influences her practice-linked identity and engagements in engineering.

A tension between Sarah's prior experiences with making and her emerging experiences in a college-level engineering program consistently showed up in her data. Since childhood, making has always been playful and oriented around conversations with materials. She kept an entire closet of recycled materials so that she could build whatever she wanted. Her parents bought her tools to manipulate materials with more precision and direction. And she was heavily involved in one of Southern California's first community makerspace education organizations. Sarah's story is saturated with experience that connects directly to the work of an undergraduate engineering major: she was creative with materials, adept with tools, able to scope and frame problems, able to explore multiple and divergent solutions, and she worked closely with others. However, coming to engineering school, Sarah felt hesitant to engage in making for projects in her coursework because she feared being judged by her peers and professors. She developed uncertainty about her decision of majoring in engineering and she felt like an "imposter" in her

college engineering spaces. Through making activities in the course designed to support students reflecting on and (re)negotiating their relationships to learning, Sarah came to a conclusion at the end of the course that making and engineering are more about her learning process rather than how impressive the final product is to other people. Here, we offer our analysis of the shifting relationships Sarah had with engineering using the theoretical frameworks of *practice-linked identity* and *history in person*.

Techno-centrality and competitiveness as the value in engineering

In the first interview with Sarah, she expressed a complicated relationship with her major:

“I feel like it’s both excitement and apprehension. I think — it’s imposter syndrome — I don’t think it’s imposter syndrome, I have — I thought about this a lot, and it’s more — it’s not that I feel like I don’t belong, but I feel like I’m not going to be able to do what other people are doing, so I don’t know what that’s called. But, um, it’s kind of intimidating with this, all these technical terms.”

She elaborated on who the “other people” are:

“I guess it has a lot to do with technical knowledge, like people who can code really well. They can just do it and I’m like, I don’t know how to do this. And people who can do electronics and put things together, and really understand it well. I can’t imagine myself getting to that point, I — like, the point — the point where professors know so much that they can have such specific interests. Like how am I ever going to know that much to be interested in the super specific sub-topic of thermal fluids, or whatever.”

Sarah was developing ideas about what is valued in engineering and negotiating her positions and identity in the community. At this point, she was intimidated by engineering because she did not have as much technical knowledge and skills compared to her peers and professors. She observed that in order to be a central figure in the community, one needs to have technical knowledge and skills and be as good as or better than others. However, she did not feel connected with these practices. This weak connection limited how she developed a strong practice-linked identity in engineering, which contributed to her apprehension towards engineering.

Although we saw Sarah’s previous extensive engagements in making activities as legitimate engineering practices [30], Sarah did not mention the connection between those experiences and engineering in the interview. Instead, her relationship with engineering seemed to be mostly shaped by the engineering practices that center techno-centrality and competitiveness.

Making as a learning process in engineering

Towards the end of Making to Learn, the relationship Sarah has with engineering appeared to be shifting. When the first author asked “how did your relationship with your major and making change over the course”, Sarah answered:

“... my mindset has definitely shifted away from like making something that’s technically impressive, sort of that the other people are like, whoa you’re good at engineering, you’re good at coding, you are good at like whatever. More being like wow, I’ve learned so much through the process. And even if the end goal, like what I come out with, is something that somebody else could have made in like two seconds, that doesn’t mean that I didn’t

learn something from it and don't have something to contribute to the — in the future. So I feel like it's definitely become — like making — my idea of making has definitely shifted from the end to the process. Which is really refreshing, and I think I needed that.”

Sarah recognized that other than creating something technically impressive, learning through making is also a valuable practice in engineering. Even if she did not produce a novel end product, she learns through the process of making. When making, she tinkers, explores materials, sees how they react in different configurations, takes risks with possible material arrangements, and learns from them. She was starting to see all these processes as valuable in engineering.

It seems like Sarah went through a process of finding her way to legitimize her participation in the engineering community and through which enacted (re)negotiations of her identities within. Being influenced by the existing narratives of techno-centrality and competitiveness in engineering, she did not feel a strong connection with the practices she saw as valued in the engineering community. However, after reflecting through making, she started to resist the idea that she is participating in the engineering community only if she makes an end product that is technically impressive compared to others. She legitimized her participation in engineering by recognizing that she can also participate in the community by learning to do engineering, even if she cannot make something as fast as others. She was positive that these practices of learning through making help her contribute to the community in the future. She saw the possibility of herself playing an integral role in and making unique contributions to the engineering community. These are evidence of her developing a stronger practice-linked identity in engineering.

The framework history in person helps us make sense of this process. The local contentious practice here is Sarah's (re)negotiation with her identity in the engineering community. When entering engineering school, Sarah encountered the history of institutionalized struggles - the marginalizing narratives of techno-centrality and competitiveness in engineering. Noticing how these narratives are preventing her from forming a practice-linked identity in engineering, Sarah sought her history - history in person - for her rich experience in making and recognized that learning through making is also a legitimate engineering practice. We will continue to analyze how her history in making prompted her (re)negotiation.

Discussion

We explored the process of an engineering student (re)negotiating her disciplinary relationships through a case study. The framework of practice-linked identity helped us understand that marginalizing narratives hindered Sarah's engagement in engineering. The framework history in person helped us to start understanding the process of Sarah's (re)negotiation of their practice-linked identity. When Sarah entered engineering school and encountered the enduring struggles within the community, in order to form a practice-linked identity, Sarah drew experiences from the past to make sense of the enduring struggles and (re)negotiated to find how she can legitimately participate in the community.

This work in progress will be further developed in the following ways. We plan to uncover how this course Making to Learn supported Sarah's (re)negotiation and how it informs the design of learning environments that support students' (re)negotiation of their disciplinary relationships.

We are looking into classroom video recordings collected over the course to identify moments when the design of the course prompted Sarah's (re)negotiation and had some initial findings to answer our first research question: "How did the activities in the course support Sarah's (re)negotiation of her relationships with engineering?". Drawing from the theory that expansive framing supports transfer [31], we theorize that the expansive framing of engineering in the course supported Sarah's transfer to see her everyday practices contributing to her engineering practices. We also saw that, unlike the projects in engineering courses that ask students to make rather uniformed end products with a limited selection of materials and tools, this course's making projects supported students to draw on what they know how to do to make their own projects in distinct ways. In this way, Sarah experienced having her assets supporting her in the making process and became more convinced that her assets can support her in engineering. We will continue this analysis to complete the development of this case study.

To move the larger study forward, we will compare the cases of other students to see if the course supported students' (re)negotiation with their disciplinary relationships in similar or different ways. We are also collecting longitudinal data by conducting semi-structured interviews with the study participants twice a year after the course ended. This helps us see how what affects students' perception of the practices in their disciplinary community, and how making can support their (re)negotiation over time.

This study contributes to the body of research on the relationship between students' development of identities and their engagement within a domain. We captured how marginalizing narratives can hinder one's developing a strong practice-linked identity. We plan to make further contributions by suggesting how the design of learning environments can facilitate students' (re)negotiation with their practice-linked identities.

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