

WIP: “We Just Did That”: Building Engineering Identity and Sense of Belonging through Team Accomplishment in First-Year Design Projects

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Abstract— This work in progress research paper explores the ways that team-based design-build-compete projects may build engineering identity and a sense of belonging during the first year of an undergraduate engineering program. We analyzed end of semester retrospective interviews of students to identify instances of the quantity and quality of interaction criteria for developing a sense of belonging and the performance and recognition factors for developing engineering identity. Early findings suggest that the design project provides opportunities to develop both identity and sense of belonging. Additionally, a sense of belonging may have helped students to buffer negative performance and recognition to reframe the project as a positive team experience.

Keywords—identity, sense of belonging, design competitions, first year, qualitative

I. INTRODUCTION

This paper explores the interaction between engineering identity and sense of belonging within student design-build-competite projects in the context of first-year engineering design courses. Design courses early in engineering degree programs (also called cornerstone courses) often conclude with a design competition in order to engage students in the engineering design process early in their education. This can motivate them with an opportunity to do engineering design instead of just math and science courses, thus providing opportunities to build engineering identity and sense of belonging in the engineering program [1]. Engineering identity has been linked to retention in engineering education [2] and sense of belonging has additionally been linked to retention for first year students [3]. Unlike engineering identity, persistence due to a sense of belonging is tied to a contextual domain - i.e. an activity, a course, or a discipline [4], or in the case of our study, interactions within a team project. Deprivation of a sense of belonging can be a detriment to health and happiness [5]. Therefore, paying attention to both engineering identity and sense of belonging in order to operationalize them in classes such as design is important for student retention and wellness outcomes.

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During the discussion of design-build-competite events [6] in interview data from our larger project on affect and engineering identity formation during the first- and second-year of an engineering degree program, we have encountered student descriptions of strong communal affective experiences. Students have expressed mutual elation and team comradery upon successfully completing the project, similar to the celebrations of NASA or SpaceX ground crews when a vehicle is launched into space [7]. They also discuss the work behind the scenes with their teammates leading up to the competition as they struggle to perform engineering tasks together to build and test their designs. We aim to unpack these strong communal affective experiences that are evident through emotionally charged language, celebrations, and collective language (i.e. “we,” “our”) used in their discussions of team accomplishments in order to describe how the design project provides opportunities to develop engineering identity and a sense of belonging. The questions that direct our analysis of the data are as follows: (1) How do students’ experiences during a design-build-competite course contribute to students’ sense of belonging in the engineering major? (2) How do students’ experiences during a design-build-competite course contribute to students’ engineering identity development?

II. BACKGROUND LITERATURE

Previous research on design-build-competite first year courses was typically evaluated through surveys measuring student satisfaction and attitudes, quantitative data showing gains in learning or retention in engineering programs, or reported experiences with the engineering design process [6], [8], [9]. This paper seeks to utilize theories and frameworks and a more fine-grained analysis to explain how this enjoyment can lead to positive outcomes including engineering identity development and sense of belonging within an engineering program.

We define the term affect as emotions, feelings, values, and beliefs [10]. Although affect can have positive, negative, or neutral valence, we will only be discussing positively valenced

affect in this paper as those were most frequently found with episodes of sense of belonging.

Factors that impact engineering identity formation for first-year engineering students have been defined in existing literature through a framework with four components: Interest, Competence, Performance, and Recognition [2], [11]. In the context of the design-build-compete project data used for this work in progress, we most commonly identified narrative about the performance and recognition factors in engineering identity formation, so we have decided to use only those two components in this work in progress analysis. Therefore we focus on those two definitions here, which have been adapted by our research team from a combination of several authors' definitions [2], [11], [12] to fit our use case. Performance is defined as a construct that encompasses both ability and belief in ability to outwardly express skills and practices relevant to engineering. Recognition can be recognition by oneself or by meaningful others as an engineering person, as interpreted by the individual.

Sense of belonging is one of a number of ways to refer to the fundamental human need for social bonds and connection [5], [13]. The concept of sense of belonging has been defined in diverse ways, and this study defines it as "a pervasive drive [for human beings] to form and maintain at least a minimum quantity of lasting, positive, and significant interpersonal relationships" [13, p. 497]. According to the 'belongingness hypothesis' [13], two criteria have been recognized as necessary to satisfy the drive to belong. The first of these criteria is "frequent, affectively pleasant interactions with a few other people" [13, p. 497], or the quantity of positive and meaningful interactions. For example, Hoffman et al. [3] observed that a learning community model that had a cohort of first-year college students take three classes together provided the opportunity for students to establish relationships with their peers. The second criteria is that "these interactions must take place in the context of a temporally stable and enduring framework of affective concern for each others' welfare" [13, p. 497]. In the Hoffman et al. study [3], learning community participants looked after each other academically and developed friendships outside of class. Furthermore, even when the conditions of a shared experience are adverse, a sense of belonging can be developed if the criteria, the quantity and quality of interactions, are satisfied, such as the camaraderie between soldiers who have seen battle [13]. From these references, we infer that students first need the opportunity to form relationships in the engineering design course through a quantity of interactions as a prerequisite to facilitating longer term, quality interactions, with both required to develop a sense of belonging even if the conditions surrounding the relationships are adverse.

Past studies have found that design experiences can encourage both the development of engineering identity and a sense of belonging [1]. While prior work comparing identity and belonging for first year engineers has focused on the context domains of belonging to the engineering major or classroom [1], [14], this paper focuses on belonging criteria within the interpersonal interactions of engineering teams. Existing literature has focused on the effect of design courses on identity and belonging, but not the how. We use a more bottom up approach to examine building blocks of sense of belonging and engineering identity through interactions. For sense of

belonging we look at the two criteria (quantity and quality) for social interactions that are both required to develop a sense of belonging rather than the concept of sense of belonging as a whole because the criteria can be more clearly observed and operationalized in a single experience. For engineering identity, we look at performance and recognition which are not criteria, but rather factors that contribute to the accumulation of engineering identity. Engineering identity is accumulated differently for each individual; for example, one student may perform well but receive less recognition than another and still form identity, which has been observed for female scientists of color [12]. An understanding of how meaningful positive interactions appear in the context of a design project may allow an instructor to manipulate the context to encourage positive interactions that can develop both a sense of belonging and engineering identity.

III. METHODS

This work is a secondary analysis of data from a larger study of affect and engineering identity formation during the first and second years of an engineering program at a small Southwestern United States liberal arts university. The design classes that are represented in this paper met for two and a half hours a week which included lecture, lab, and fabrication performed in the makerspace. Class sizes were typically between 15-20 students with three sections fall semester and two sections spring semester. Many students in the sampled cohorts are in multiple engineering, math, and science courses together due to the small number of sections and required courses of the engineering major. The data selected for analysis is from the fall and spring semester retrospective interviews of the first cohort near the end of or after the conclusion of each semester. The approximately two hour semi-structured interviews were recorded using the Zoom video conferencing platform and professionally transcribed by rev.com. Fall data consisted of 17 interviews and 13 returned for spring interviews.

Data analysis began with a keyword search of the interview transcripts in order to locate the discussions of the design competition project and the corresponding teamwork throughout the semester. The general search terms that were relevant for both semesters were 'design', 'team', 'group', 'competition', and 'project'. For fall semester, the additional terms 'catapult' and 'launcher' were used to locate the project by its description. For the spring semester, the additional terms 'car' and 'chem' were used. When we found the above terms in our search, we used deductive and inductive thematic analysis [15] with techniques from discourse analysis to examine the structure and words of our participants [16] to ensure that they refer to discipline related affect and identity. For this work in progress, we selected vignettes with positively valenced affect (e.g. happy, cheering, fun) or positively valenced phrases (e.g. "we just did that"). From there, we coded for the two criteria to develop a sense of belonging (quantity and quality) and factors that contribute to identity (performance and recognition).

IV. FINDINGS

The data that provided detailed, emotionally charged discussion of the design project and team relationships caught our interest because it emerged spontaneously from questions about feelings while solving challenging problems (Hope,

Dante, Taine), students' favorite part of classes that semester (Projector Man, Dante), and what experiences caused the strongest positive emotions that semester (Noelle, Dante). First we will review the experiences of Projector Man, Hope, and Taine at the design competition, followed by some insight into the activities happening behind the scenes as the students worked on their projects outside of class shared by Projector Man and Noelle, and ending with Dante, who divulged his team's evolution throughout their design project.

When asked about his favorite part of all of his classes so far, Projector Man discussed the feelings of camaraderie and closeness that the class collectively felt upon accomplishing the required engineering tasks at the design competition.

Projector Man (Spring): It was incredibly frustrating whenever we failed the first time but whenever we accomplished the same task, that was an amazing and elating feeling. And then afterwards, we were just like, yes, all of our work was very, very worth it. And it was a moment of comradery among, not just our team, but among all the teams of like, "we did this, y'all." And that's something that I've noticed with both of my design classes so far, is there's always just a sense afterwards among everyone there of, "we just did that. We made this thing do this task in a semester." And it always brings everyone in our class closer together.

Projector Man discusses collective accomplishment and making their project do a task in a semester, which we coded as performance. He also expressed recognition for their team and other teams' accomplishments with statements like "all of our work was very, very worth it" and "we just did that." The words "camaraderie" and "brings everyone in our class closer together" are evidence of high quality interactions within this group of students that encompasses not just the team, but the whole engineering class.

Hope similarly identifies finally getting her group's project to work during the design competition as a moment that brought everyone in the class together, including the teaching assistants.

Hope (Fall): It was probably the happiest I've ever been in, at least... Yeah, I would say that was the happiest moment since starting college. I remember we were all cheering and jumping up and down, and we had all these other people who were also in the class, but also the TAs were watching. But yeah, it was a super happy moment that we finally figured it out.

The team's performance when they finally figured out how to make their catapult work was celebrated by her team, who were "all cheering and jumping up and down," and other classmates and TAs came to watch, which implies a quality relationship of support and affective concern for each other. She also describes it as a "super happy moment" for her team, which could contribute to the affectively positive interactions that build on quantity and quality of interactions. As an individual, it was her "happiest moment since starting college." Taine (Fall) described a similar experience to Hope of performance and group recognition of themselves at the design competition and the resulting happiness: "Yeah, it felt good. There was more of a group sense of achievement, so it made us all quite happy."

The day of the design competition provides a snapshot of students' developing identity and sense of belonging at the culmination of a semester of working together, but it is not the only time during this project where students have described quantity and quality interactions with each other as they performed engineering tasks. Projector Man describes the work happening behind the scenes on weekends outside of class time.

Projector Man (Fall): I think my favorite part of my STEM classes in general was at the end of our freshman design project where there were a ton of engineering students all just in [an engineering space] on the weekend just testing out our catapults. That was so fun. I got to talk to a bunch of my friends and I got to see this work that I had done throughout the semester. I got to see it happen. I got to see it. I got to test the thing that I've been designing for so long.

Not only did Projector Man experience successful performance of engineering tasks - "I got to see it happen," but this activity also extended the quantity of interactions with his engineering peers and friends outside of the classroom into his free time, which he described as a good quality experience - "That was so fun." Noelle also describes her experiences of working after class hours with a teammate.

Noelle (Fall): ... In my design one class, building this catapult with one of my group partners who is very engaged and putting in a lot of work with me, it's just been fun when we've had to stay very late until midnight and we are working on our catapult and stuff's not working and everything becomes funny at that point, but then making it work and making it perform very well by the end of the night, just going through those mini highs and lows, it's pretty fun when it comes to that.

The drive to perform the engineering task of building a working catapult led to the teammates spending a large quantity of hours together staying "very late until midnight," experiencing quality interactions of having fun and everything becoming funny as they navigated the "mini highs and lows" of their performance.

Dante describes how his team evolved from thinking that they could not work together to performing well and recognizing themselves for their team performance at the competition.

Dante (Fall): At first I was kind of disappointed because I learned I would have the same team members that we had done for a previous class project, and that one didn't really go so well. We did the worst in the class. It was like, "Oh, this is going to be bad. I'm going to hate this." But then as we actually worked together more and discovered that we actually can do stuff well together, I actually started enjoying the class more...

Dante (Fall): I would say the biggest positive emotion was how good we did in the actual catapult competition and how we were able to come together as a team and worked out really well together, especially compared to some other teams. And I just feel confident and just positive that we just went in and nailed the competition, at least the physical catapult part...

Dante's team performed poorly together in the past, so he began their team experience on the catapult project with a negative attitude about it. However, he observed that through the quantity of interactions as they "worked together more," they discovered that they had quality relationships and "can do stuff well together," or in other words perform engineering tasks, which leads to more enjoyment of the class. The team's ability to perform together was validated through their successful performance at the competition, which led Dante to recognize himself and his team for coming together and "nailing the competition."

V. DISCUSSION

Students in this study shared their lived experiences of working together throughout the semester, culminating in the design competition where students experienced strong positive affect communally that can serve as the criteria for developing a sense of belonging (quantity and quality of interactions) and/or factors influencing the development of identity (performance and recognition). Within a given experience, we found that there is interplay between the sense of belonging criteria and engineering identity factors. The performance of engineering tasks to meet the requirements of the design project led students to a high quantity of interactions with their teammates and other classmates, as expressed by Projector Man, Noelle, and Dante, who all shared their experiences of putting in time with teammates as they worked on their performance. This performance led to self-recognition or public recognition of their team's accomplishments at the competition for Projector Man, Hope, Taine, and Dante with emotionally charged experiences such as happiness and celebration that at times extended past the individuals' teams to the entire class, indicating a high quality of meaningful and positive interaction. The context of this small university and engineering cohort may contribute to the students' sense of belonging due to its inherent similarities to the learning community model [3].

We also have noticed indications that a sense of belonging may buffer negative performance and self-recognition to allow students to reframe the project as a positive team experience. For example, Dante attributing his team's positive performance after past struggles to their ability to come together and develop positive relationships as a team, Noelle's positive experience of the mini highs and lows of her design's performance with a teammate, and Projector Man and Hope's experiences of overcoming frustration with designs followed by observations that performing engineering tasks together united the whole class. Our interpretation of the interplay between engineering identity and the criteria for sense of belonging is shown in Fig. 1. Since we posit that sufficient quantity of interactions enables quality interactions, we plot quality of interaction against engineering identity factors of performance or recognition. This figure shows that the quality of interaction allows engineering identity and sense of belonging development even for cases of poor performance and recognition, perhaps allowing students to reframe those experiences for their personal gain. The level of challenge and demand on the students to complete this design project may encourage them not only to engage deeply with the design process to practice their performance of engineering tasks and form identity, but also to engage in more frequent and

deeper interactions with each other, setting them up to develop a sense of belonging if team interactions are of high quality.

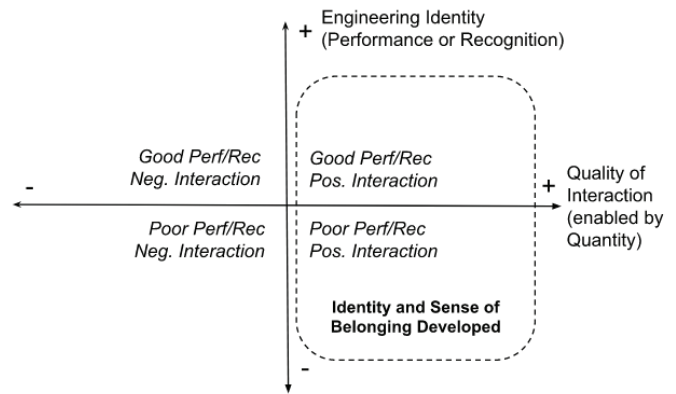


Fig. 1. Engineering identity versus quality of interaction

This work in progress analysis also improved our understanding of strategies for interviewing about identity and belonging. Asking students about affect within an experience and not directly about belonging or identity encourages a more narrative and in-depth reflection that we have found includes more details about their sense of belonging and identity development. Unlike questions in other studies [1], [14] or in our own interview protocol that directly asked students if they identify or belong in engineering which lead to students telling us their answers, affective questions elicit rich responses in which students show us how sense of belonging and identity occurred through the doing of engineering. This provides a qualitative technique to analyze whether a design-build-compete project is creating opportunities for students to develop engineering identity and sense of belonging rather than solely surveying students about outcomes.

VI. CONCLUSIONS AND FUTURE WORK

Throughout this work in progress paper we have revealed how the criteria for sense of belonging and factors for engineering identity are entwined throughout the process of designing, building, and competing also noted by other scholars [1], leading to strong affective experiences for students. We have also noticed that a sense of belonging within a team appears to play a buffer against frustration and poor performance to allow students to reframe and feel achievement from the end result of the competition. We hope to further explore this buffering in future work. Since the criteria for selecting vignettes containing identity and belonging described in our methods resulted in the use of responses from only 5 participants, their responses and interactions may not be a typical or complete representation of the 17 total participants. This work in progress focused only on the data that discussed affect with positive valence. We hope to expand on this paper to add discussion of affect within this phenomenon and to examine trends in data with negative valence from the same data corpus. We also hope to expand the scope of the sense of belonging framework to include the broader construct of sense of belonging and consider the other two factors of engineering identity development (i.e. competence and interest).

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