The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
Paper ID #43359

”Fail a little, succeed a lot”: How Experiential Learning Influenced Civil Engineering Students’ Approach to Coursework

Dr. Noel Hennessey, The University of Arizona

Noel Hennessey is the Director of ENGineering Access, Greater Equity, and Diversity at the University of Arizona College of Engineering. She oversees a suite of research informed and evidence based initiatives designed to improve underserved students’ sense of belonging and engineering identity development.

Dean Papajohn
Tyler Jean Le Peau, The University of Arizona

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Introduction

The U.S. workforce needs engineers, and current enrollment, persistence, and graduation in undergraduate engineering programs are not on track to meet those needs. Civil engineers design, construct, and manage projects to meet society's need for transportation, water, buildings, bridges, water and wastewater treatment and other infrastructures. With continued U.S. investment in these backbone systems, the demand for civil engineers is increasing at a rate of 5% over the next 10 years which is faster than the average for all occupations [1]. Like other engineering disciplines, an entry level position requires a B.S. degree.

Not all civil engineering students are the high school students who are attracted to the high salaries and appeal of high technology of other engineering disciplines. To meet industry demands, the pool of students must be broadened. Thus, civil engineering departments must expand and improve their student support to retain and graduate students. Engineering education is rigorous, and traditional methods to support student success have included tutoring, supplemental instruction, and workshops on meta-cognitive learning and time management strategies. Workforce training through internships is often reserved for students who have "made it" through their early course work and have reached their upper division technical training. Research on experiential learning and its impact on persistence indicates that earlier experiences with hands-on workforce training are beneficial, especially for students from underserved and marginalized backgrounds, such as low-income, first-generation, and students of color [2]. The NSF supported Building Pathways project is examining the efficacy of student interventions in a direct comparison to identify the support to achieve those outcomes with emphasis on underrepresented minorities, women, low-income, and first-generation university students.

Guiding theory

Student success outcomes have long been defined in higher education scholarship in institutional terms. Whether students persist to the second year has traditionally been seen as a strong signal indicating their likelihood to graduate [3][4]. Full time enrollment, grade point average, and time to completion are also indicative of successful student support programs. But contemporary scholars point out that these outcomes are situated within the viewpoint of how the students impact the institution, and less concerned with how students are intrinsically impacted by their education. Outcomes such as civic engagement, leadership, critical consciousness, and belongingness have been dubbed *liberatory outcomes*, a name reflective of the liberation that education is meant to provide [5][6].

At the outset of this study, we hypothesized that a comprehensive student support program would embody academic outcomes and support students' access to and comprehension of rigorous engineering coursework, but that students also needed to feel that they belonged, not just in their educational pathway, but in their future profession. Strayhorn [7] defines *sense of belonging* as "students' perceived social support on campus, a feeling or sensation of connectedness, and the experience of mattering or feeling cared about, accepted, respected, valued by, and important to the campus community" (p. 5). The research-informed interventions integrated into the Building Pathways program model are designed to cultivate students' sense of belonging.

Beyond a sense of belonging in engineering education, belongingness in the engineering profession is often referred to as *engineering identity*. Recognizing oneself as an engineer—someone who is technically competent and can connect with the professional community—is a core tenet of engineering identity development [8][9]. Experiential learning is an effective vehicle through which students begin to strongly identify as an engineer, but many experiences such as internships and undergraduate research are only available to students who have reached advanced coursework. A working assumption is that students may not be ready for highly technical work until they advance through foundational coursework, but evidence suggests that experiential learning and subsequent development of engineering identity helps students persist in engineering. Building Pathways was designed to incorporate such experiences earlier as a modality to help students persist in engineering.

Our study is situated in the context of civil engineering, as two of the PIs are civil engineering faculty members, but it should be noted that we often refer to engineering education in the aggregate. This is partially because students at our institution do not declare a specific major until they complete some foundational coursework in math and science. The interventions in this study are designed specifically with civil and architectural students in mind, but they may be translated to other disciplines.

Building Pathways Programs

The Building Pathways program features academic and professional development programming for engineering students during the first and second academic years and during the summer terms following the first year. This paper focuses on data from the summer term, of which there are two program options: a summer intensive program that combines cohort-based foundational coursework and a career development workshop, and a summer internship preparation class and company placement.

Summer Intensive

The summer intensive program runs for ten weeks in the summer, and students enroll in foundational math and science courses (either first-semester calculus or second-semester calculus *and* introductory mechanics) and a career development course that combines classroom lessons and discussions of professional skills with on-site job rotations. The foundational math and science courses are strategically scheduled as a cohort, where students can benefit from the psychological safety of an intimate learning community [10]. The career development course integrates themes of professional competencies such as communication, collaboration, project management, and entrepreneurial mindset with visits to regional engineering companies and ongoing check-ins with professional mentors. The data collected for this paper were from the summer of 2023, in which13 students enrolled in the Building Pathways track of this program. (There were two other disciplinary tracks not related to this study).

Summer Internship

To attract more students to heavy construction, our team worked with industry partners to create internships for construction engineering management students after their freshman year. Heavy construction companies need more construction engineers, so they saw this program as a win-win. The internship program is advertised to freshmen engineering students in their first semester before they declare a specific engineering major. Interested students complete a one-page application and submit it with their resume. A faculty member in construction management meets with each interested student one-on-one to make sure they understand what heavy construction is and what an internship in heavy construction looks like. Resumes and applications of all screened students are then provided to a group of industry partners, who review these documents and decide what students, if any, they would like to interview. It is up to each company to decide whether to extend an internship offer to a student.

Most students have internship placements by the end of December, though some students are not placed until the spring semester. During the spring semester, students in the program register for a one-credit internship preparation seminar. The seminar introduces students to the heavy construction industry. A faculty member facilitates some sessions on topics such as construction plans, details and specifications, construction safety, and sustainable construction. Industry guests present on topics such as concrete construction, paving, temporary structures, shoring and deep excavation, resolving conflicts in the field, and project documentation. Students learn more about the companies they will be interning with and create an asset map to reflect on how their unique combination of characteristics, skills, and experiences might help them in their internship. Students also complete an industry safety certification called OSHA 10, which consists of 10 hours of online construction safety training.

Internships begin in May after the spring semester ends. During the summer, a construction management faculty member periodically checks in with the student interns to see how their internship is going, answers questions, and helps with any problems. The faculty member also checks in with the supervisors of the interns to hear more about what the intern is involved in and how the intern is performing, and if there is anything else the University can do to prepare and support the interns. In the spring and summer of 2023, six students participated in the internship component of Building Pathways.

Participants

During the summer of 2023, there were 19 students involved in the Building Pathways summer programming. Enrollment by program and descriptive demographic information is broken down in the table below, which also compares the Building Pathways program demographics to the 2022 incoming freshman class. Building Pathways students in both summer programs had more representation of women, students of color, low-income, and first-generation college students than the overall freshman class that year.

Table 1. Demographic breakdown of Building Pathways 2023 summer students compared to College of Engineering 2022 entering cohort

	n	POC	Non-POC	First Gen	Non-First Gen	Female	Male	Pell	Non-Pell
Engineering	**633**	**40.8%**	**59.2%**	**21.4%**	**78.6%**	**30.6%**	**69.4%**	**22.9%**	**77.1%**
Building Pathways	**19**	**68%**	**31.6%**	**47.3%**	**52.7%**	**47.3%**	**57.9%**	**47.3%**	**52.7%**
Summer Intensive	13	84.6%	15.4%	53.8%	46.2%	38.5%	61.5%	53.8%	46.2%
Internship	6	33.3%	66.7%	33.3%	66.7%	50%	50%	66.7%	33.3%

Research Questions

1. Do the summer intensive and internship programs impact students' self-reported sense of belonging or engineering identity?
2. To what do students attribute these changes? How did their experiences in their respective programs influence their feelings of belonging in their majors and their profession?

Methods

This study utilized a mixed-methods approach to understanding how students engaged with and were impacted by Building Pathways summer programming. Using retrospective pre- and post-surveys, we deployed validated survey instruments to understand how students perceived their respective intervention's impact on their sense of belonging at the institution and their identity as an engineer. Students in each intervention also participated in focus groups in August 2023, shortly after they completed their respective interventions.

Surveys

To understand the interventions' impact on sense of belonging and engineering identity, program participants responded to a retrospective pre- and post-questionnaire that combined two validated survey instruments: Godwin's [9] engineering identity scale and Hanauer et al.'s [11] measure of persistence in the sciences (PITS). The PITS combines five other validated instruments that measure project ownership-emotion, project ownership-content, science identity, self-efficacy, scientific community values, and networking on a five-factor scale. These variables have been shown to predict psychological factors that influence students' intent to stay in science and engineering disciplines. The engineering identity scale is a five-factor instrument. It was adapted from a science identity scale and validated through a factor analysis. We used it to specifically track students' identification with the engineering profession, and variables explore students' perceptions of competence and recognition as increasingly proficient members of the engineering profession. The rationale behind using both instruments lies specifically in the phenomenon of attrition from engineering into other STEM disciplines. Pairing psychological variables that predict students' intention to remain in sciences with those that measure how connected students feel to engineering, specifically, can help us understand in what ways engineering education interventions need to emphasize competence and value in engineering.

Participants in this study responded to our questionnaire once, answering retrospectively for before they participated in their respective interventions—the summer intensive program or their summer internship—as well as providing answers representing their contemporary feelings for each variable. The decision to provide students with a single point in time to respond to the survey, rather than administering a true pre-survey prior to the interventions, was informed both methodologically and logistically. It was less burdensome to the program participants to complete the questionnaire once, which made it easier to make sure we had responses from every participant. Evidence also suggests that retrospective pre-surveys capture a more accurate portrayal of participants' understanding of their own growth and change due to the ceiling effects of the traditional pre-test [12]. Participants were sent the survey through their email and were sent a reminder to complete if they hadn't already on the day of their focus group.

Focus Groups

We conducted two separate focus groups—one with the summer intensive students and one with the internship students—to understand the mechanism for how students engaged in the process of change during their respective interventions. We wanted to know if there was a difference in students' intent to persist (sense of belonging) or engineering identity, to what did students attribute those intrapersonal changes. Each focus group had a protocol specifically designed for the intervention in which students participated. The summer intensive focus group had 13 participants and lasted about two hours. The summer internship group was much smaller (n=6), and the discussion lasted about an hour. Protocols asked students to describe their experiences and share their understanding and perspectives.

The design is drawn from Seidman's [13] phenomenological interview sequence. Though these were focus groups, rather than individual interviews, and it was a single conversation (as opposed to Seidman's three-interview sequence) the framework follows similar logic, in that participants can make sense of their experiences when they situate them within the broader context of their personal educational narrative. Students discussed how they found the Building Pathways program, experiences that led to their decision to participate, and drew meaning from their interactions within the program. Narrative is important in educational research on student interventions, as people will behave based on their perception of reality irrespective of how closely aligned that perspective is to reality [14].

By analyzing survey data and focus group transcripts, we aimed to understand how a strong sense of belonging and engineering identity is cultivated. Future data analysis aims to determine whether these factors are predictive of academic persistence, particularly among demographic groups who disproportionately struggle to access and persist in engineering education.

Results and Findings

Our analysis demonstrated positive trends for engineering identity and sense of belonging. All 19 participants are still students in the College of Engineering, and although that is a positive outcome, a single outcome without a comparison group makes it difficult to know whether the elevated sense of belonging and engineering identity impacts retention.

R1: Do the summer intensive and internship programs impact students' self-reported sense of belonging or engineering identity?

To evaluate whether the summer intensive or internship programs had an impact on students' self-reported sense of belonging or engineering identity, we developed composite scores for each assessment for each participant by averaging their answers across each respective the survey instrument within the questionnaire. Although there was a positive change in both sense of belonging and engineering identity, the relatively small sample size *(n=19)*, there was no statistical significance.

Table 2. Average change in attitudes towards

	Pre-survey average	Post-survey average	p-value	Average Change
Sense of Belonging (PITS) (1-5)	3.00	3.98	0.99	0.98
Engineering Identity (EI) (1-5)	3.49	4.35	0.99	0.85

As this is an ongoing study, we will continue to add observations over the next three years, and we will aim to grow a robust sample that can demonstrate significance. Even in the preliminary sample without statistical significance, some of the larger changes in responses across individual questions tie directly to the program design.

Confidence in understanding engineering outside of class. Among the questions in the Engineering Identity tool, one illuminated the impact of experiential learning for students in the program. When asked to rate their agreement with the statement, "I am confident in understanding engineering outside of class," students' self-rating jumped from 3 to 4.2. In the context of the Building Pathways program, this illuminated the relevance of contact with professionals in their working environment. It also demonstrated ways in which students' engineering identity-building experiences prior to the Building Pathways program were perhaps deficient in external exposure to the engineering profession, as the average pre-score for this question was among the lowest in the collection of questions.

Belonging in the engineering community. The cohort design of the program, with students learning alongside peers with shared experiences, enhanced students' connections to the engineering community. Among the four questions presented to assess students' perception of their value in the engineering community, largest change was in the question "I feel connected to the engineering community." Again, this points to an early indication that the intentional cohorting and community-building among peers, as well as the intentional connections made between the students and the engineering industry, may influence students' feelings of value within the engineering community. This will be assessed further with future data collection.

R2: To what do students attribute these changes? How did their experiences in their respective programs influence their feelings of belonging in their majors and their profession?

Through the focus groups, two major themes arose in students' narratives about their experiences as they related to sense of belonging, engineering identity, and persistence. First, mentor validation gave them an understanding that mistakes are normal, and that “failure” is not a signal that you cannot participate, but rather, that you need more practice participating. Second, experiences either *doing engineering work* through an internship, or *learning about the everyday experiences, decisions, and processes of engineers*, helped students visualize their futures in the profession.

Fail a little, succeed a lot: Validation builds resilience. Validating student experiences has roots in HSI research that predates HSI research. Rendon [15] discussed the role of validating students through interactions with professors, speaking home languages in professional and academic spaces, and building culturally relevant leadership experiences. Garcia, Sansone, and Nunez [16] discuss the ways in which validating experiences can counteract campus microaggressions and negative campus racial climate. Students in the two focus groups described ways in which their mentors validated their learning process as normal, building resilience against the perfectionism that many students stated they previously brought to their work. An intern, Lexi, described a discussion she had with her mentor at a construction company:

> My mentor, the project manager, she had just signed on to [this company] like a year prior. So, she was like, “I'm still learning how to do it [this company’s] way,” because across industries everyone has their own way of doing something. So, she's like, “if I don't know how to do something [here], I'll look at like someone else's job project folder.” … And she was like, “sometimes I still make mistakes. Like I made a mistake on like the pay application that goes to the actual owner, and the people who bill it and stuff.” And she was like, “yeah, I like mess up the quantities on there all the time, you're all good…”

For Lexi, understanding that someone she was learning from makes mistakes and views them as a normal part of the learning process was validating. It gave her the confidence to try, and every time she was able to complete a task as an intern, she felt more like an engineer. Further, when I probed about how normalizing making mistakes might impact how the students approach academics, Lexi shared:

> I failed one of my calc tests like freshman year. And I was like, I'm not going to be an engineer like this isn’t going to work out. I should just switch to business… but in our internship…when I got that pay application thing wrong, I was like, “oh, I like I need to get it right for Jamie, my boss, next time.” So, it was like a good thing like “oh, I made an error, but I can correct it next time.”

The process of being given permission to fail allowed Lexi to practice professional tasks without the anxiety of an all-or-nothing approach to learning, and that permission to make a mistake came from validation from her mentor, who normalized learning through making (and taking accountability for) mistakes. Lexi connected the experience back to academics as well:

> I feel like it’s like, fail a little, succeed a lot. Like that’s my rule of thumb. It’s like, yeah, some things are going to get thrown your way. In the moment it seems really hard, and like you’re not going to get past it, but there’s always a change to do better on your next

> one… like maybe you didn't do good on that course the first time, like hopefully, you can strive harder and study harder for the next time.

Other students echoed Lexi's sentiments about the experience of *validation* through their relationships with their mentors. In the summer intensive program, students were not employed as traditional interns, but they interacted with professional mentors throughout the summer and had the opportunity to connect with engineers who hosted company tours or came to class as a guest speaker. Thomas, a student in the summer intensive program, shared this takeaway from one of the guest speakers:

> I really like that, the speakers, whenever they go into depth about like their career in their career path, it wasn't linear. Like they didn't go from like one step to the higher tier to the higher tier. They, like, I don't want to say they failed, but they were-- they had their setbacks, right? Like, sometimes they would, you know, make this brand-new company, and then it just fails overnight. Then they have to start from square one over again. Or they were doing a project with a company that was supposed to change lives. But then the company went under, and how they just never gave up.

Another student, Sarah, chimed in: "It's almost comforting to know that, like other people, have failed and just gotten back up and have still become a successful engineer." Students in the summer intensive program interacted with one another in their career development class, but also took foundational math and science courses together. Their discussion around their interactions with instructors showcased the ways that normalizing mistakes as part of the learning process is not a validating interaction that is limited to professional contexts. Additionally, invalidating experiences were just as impactful, but detrimentally so.

A subset of students took an Introductory Mechanics (physics) course during the first half of the summer, then took second-semester calculus during the second half of the summer. They described their interactions with their physics instructor and lab teaching assistant, as well as their calculus tutor, as validating. Another summer intensive student, Antonio, shared: "[Our tutor] always implies that, you know, he believes in us. And every single time we go to office hours, like 'You're making the right choice' to like kind of improve ourselves and improve like our understanding of the fundamentals."

Antonio's assessment of the math tutor was not so much an evaluation of his teaching, but his intentional choice to reassure students and positively reinforce accountability in their approach to learning. Devyn, a student who took first-semester calculus over the course of the summer shared this about her teacher: "I feel like really, at least every single day she like tells us, or like implies, that, like she believes in us, which is like really great." When pressed to explain the impact of an instructor's belief in her, she shared:

> Um, I think it pushes me to try harder. I feel like if someone else doesn't believe in me, I'm just kind of like, "oh, they're right." I'm just kind of like shut down, but when she tells us, "I believe, like, you guys can do good on this test," or "a third of you can get A's," it makes me push harder to prove her right, I guess, like it's if someone's believing in you and putting this effort into you want to show them that there's like a reason why

> they think that. And so, I think that's really great. And she's not just like. “Oh, like, here's your grade all done” she like, “here’s your grade, here’s how you can improve.”

Devyn and Antonio both seem to describe a sense of commitment to their own learning that is at least partially fueled by their instructor/tutor’s recognition of their effort and potential. It’s especially telling that Devyn described her instructor’s feedback as positive, because she isn’t describing someone who is being excessively easy on her, and she didn’t describe an easy class.

Similarly, though, invalidating interactions with instructors can have a counteractive effect. Though the second-semester calculus tutor was seen as validating, students described invalidating interactions with corresponding second-semester calculus instructor. Sarah shared the following about that instructor:

> He has like a habit of dismissing questions, almost so, yeah, someone will ask a question and he’ll be like that doesn't matter, or we'll come back to that or something like that. And that just doesn't feel validating.

Axela, another second-semester calculus student, followed with:

> Or if there's a fundamental thing that we're supposed to know, he's like, “Oh, you're supposed to know that.” …A lot of times it's like, I just need like a little refresher. I know that I appreciate in the past, like when instructors--like, briefly went through a fundamental we might have forgotten, because it might have been like, you know, I mean, like two semesters ago, or something. And we were supposed to know this. And I really like going back to the basics. I think it's helpful.

Overall, students’ positive interactions with engineers and instructors who normalized mistakes and humanized the learning process had the impact of building students’ sense of confidence that they can take time and space to learn, and that accountability to proficiency isn’t the same as perfectionism, because the former allows for mistakes as part of the process.

The kind of engineer I want to be: Culturally sustaining proximity cultivates engineering identity. The perceived impact of proximity was another theme that emerged from both focus groups. The students in both groups were rising sophomores, and neither anticipated that they would have access to engineering professionals at this stage of their educational career. That proximity gave them the opportunity to consider the daily life of an engineering professional and picture themselves in that role. Antonio, from the summer intensive program, shared:

> Honestly, I feel like this course kind of helped me get a picture in my mind of the engineer I want to be. Like kind of taking different parts from different speakers, finding out what industry wants, and definitely learning about what industry needs, too. And a lot of skills I need to develop right now and what I need to work on myself and prepare for industry.

Getting to know mentors who shared personal or cultural characteristics also had the effect of creating credibility over a shared experience. Savana shared the following about her mentor:

> I'm architectural, and my mentor is a systems engineer, but once we started talking, we realized we had a lot more in common, like to a kind of weird degree. Where she was also first-gen, Hispanic, part of SHPE. She had the exact same job that I have right now on campus. Um, so--I was able to see sort of like somebody who is on the same path, or has taken a very similar path, and she was able to sort of reflect on her own experience and say, "Hey, this is what helps me. You should give it a shot."

Those who participated in internships were able to cultivate their engineering identity through applied work, but their proximity to engineering professionals and the ways that they related to those engineering professionals helped students form a picture of the engineer they would be upon graduation. Ned shared:

> I was in the pre-construction office. I think I was like the only person here who wasn't actually on a project. So, a lot of quantity takeoffs, looking up specs, just trying to like assist estimators, and any kind of monotonous work, you know. So, it was cool, like learning from everybody, though, because they obviously everyone in that office was super knowledgeable. I'm kind of hoping to get out on a project next summer. But like long term it's definitely cool work. So, I think my plan like post college is, I want to move around as much as possible. So, field engineer work could be cool for a while, but at the end of that line if estimating is it, I enjoyed it. I thought it was a cool process.

Another intern, Logan, shared that although he was often unsure of what to do as he learned on the job, the opportunity to work alongside engineers has given him the grit to push through challenging coursework:

> A lot my time I spent just looking through the employee files because I had access to it so I could read anything that I want and look up any work plan or anything. So, I would just spend my time looking through that whenever I had downtime. So, I just figured things out as I went… Working the type of work doing we were doing, it just, it made me feel very content. So, it helps me to want to push through all this hard work. So, I could be there again.

The theme of proximity—to both the work and to engineer professionals to whom students could relate—cultivated identity because of how it reflected to students how they could fit into the engineering profession. Whether that was because of how students developed confidence and cultivated joy in what they were doing, or because they understood engineers with whom they interacted as complex humans with similar experiences to their own, the proximity to the profession appears to build engineering identity through the mechanism of sustaining students' culture. If students could see an older version of themselves, with similar personality traits, experiences, and cultural values, in an engineering career, it contributed to their feelings of belongingness in the discipline.

Discussion

Based on our preliminary results, the evidence-based interventions designed to build students' sense of belonging and engineering identity did what they were intended to do. That's unsurprising, but how students made sense of these newfound beliefs may lead to more novel research questions. Students described a level of confidence in their abilities that protected them from the anxiety and overwhelm that stem from perfectionism. Their comfort in making mistakes—and realization that they are not defined by them—is perhaps the most valuable attribute that their newly cultivated engineering identity can give them moving forward.

This finding leads to another paradigm—that intrinsic, psychosocial, liberatory outcomes may support normative, academic outcomes, rather than vice versa. These ideas have important implications for consideration in policy and in practice. When students' feelings of belonging and community are more informative of their academic persistence than grades and test scores, engineering educators may consider ways that they can build opportunities to connect with the profession into earlier parts of the curriculum.

Implications for future research/data collection/analysis

Future research will analyze students' academic performance and persistence in engineering compared to demographically similar students. We hope to explore the extent to which a focus on liberatory outcomes may particularly impact persistence in students from historically underrepresented backgrounds. Additionally, the degree to which a student's pre- and post-scores change and the extent to which that change may signal persistence will also be a topic of exploration. We would like to understand the connection, if any, between psychometric variables and institutional outcomes. The possibility that there may be a threshold by which students, particularly those from underrepresented backgrounds, would benefit from engineering identity and sense of belonging enhancing interventions has major policy implications.

We also intend to collect and analyze data about labor outcomes (including future internship and full-time employment offers) and leadership engagement on campus as it relates to cultivated sense of belonging and engineering identity. As practitioners/instructors, we intuitively understand that no single intervention can be assumed to be a determinant of academic achievement and success, and that multiple interventions have a compounding effect on overall academic achievement. In this project and beyond, we intend to monitor student engagement across campus and in the community and examine these preliminary interventions' impact on student engagement.

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