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An Introduction to Chemical and Biomolecular Engineering Course Redesign Supports Students' Engineering Recognition Beliefs

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Abstract

Introductory engineering courses shape college students' college expectations, motivation, and engineering role identity. Engineering role identity describes the ways in which students see themselves as the kind of person who can do engineering and is often described by three key beliefs constructs, one of which is recognition. Recognition beliefs—feeling that meaningful others to students (e.g., peers, faculty, TAs, etc.) see them as engineers—are the most essential components of identity development in engineering for first- and second-year students. While much work has been done to link classroom experiences to engineering identity development, fewer studies have investigated course redesign as an intervention to support these outcomes. Often, these course redesigns focus on one aspect of the course such as content (what is taught), pedagogy (how it is taught), and assessment (how learning is assessed). This work describes a mixed methods study of the impact of a complete course redesign guided by engineering role identity theory. The course is an elective introduction to chemical and biomolecular engineering that engages teaching through food to connect to students' everyday lives (content), provides hands-on learning opportunities in an accessible and safe way (pedagogy), and leverages alternative assessments. Pre- and post-course survey measures of recognition and self-report multi-select demographic measures were gathered from 42 students. Additionally, six students participated in semi-structured interviews. These qualitative interviews add more detail and description to the changes in recognition seen in the survey responses. On average, recognition beliefs increased by 20% from the beginning to the end of the course, and women had almost two times the increase in recognition beliefs than men. The qualitative results indicate that students felt recognized by several different sources throughout the course. These results highlight some key sources of recognition for students in an introductory engineering course and provide options for instructors who wish to support engineering identity development more effectively.

Introduction

First-year engineering courses often serve as the first domain experience many undergraduate students have in their careers. These courses have a lasting impact on engineering students by setting their expectations for college [1], identifying viable major pathways [2], and supporting motivation to continue in the major [3], [4]. Often, engineering courses emphasize repetitive close-ended problem-solving, high-stakes summative assessments, and content rooted in conventional engineering applications (e.g., petrochemical processes for chemical engineering) [5]. While this course framework has been utilized for over a century, some aspects of this model negatively affect engineering identity development. Direct instruction does not encourage much engagement in class, burdening students with outside-of-class rehearsal as the main learning mode [6]. As such, students may perceive lower beliefs about their abilities to understand engineering and do well in engineering courses. Summative assessments may place the focus in courses on grades over growth and reinforce a static mindset of who can become an engineer [7]. Additionally, content rooted in conventional engineering applications can cause students to feel less motivated or disconnected from the major due to a difference in interests within the field.

Alternatively, many general first-year courses have integrated active learning or design-based pedagogies [8]. However, these courses are typically focused on general engineering and often have large enrollments. Additionally, design projects in these courses are often mechanical or electrical engineering focused as those fields provide easy and relatively safe hands-on entry prototyping opportunities. As such, they may connect less with chemical engineering students' identity development.

Numerous course redesign ideas have been implemented to mitigate these problems including the use of active learning in classes [9], alternative grading schemes [10], and novel course content (refer to the Food for Thought column in Chemical Engineering Education, with articles such as [11]), and have shown promising results. However, these course redesign efforts often only focus on changing one aspect of the course (content, assessment, or pedagogy) and rarely examine how these changes affect student beliefs that have long-term impacts on student retention and development, such as career goals or engineering identity development. Engineering identity development in particular is of importance due to its effect on factors such as retention [12] and career choice [13]. This study takes a comprehensive approach to course design by considering content, assessment, and pedagogy together. Examining the connection between course redesign and student outcomes demonstrates what strategies are successful in helping students navigate the major and ultimately become engineers. This work explores the effects of a complete overhaul of an elective first-year engineering course on student recognition as engineers by answering the following research questions:

RQ1: How did student recognition beliefs change throughout the course?
RQ2: What sources of recognition beliefs emerged throughout the course as important in student experiences?
RQ3: What were the push and pull factors associated with students' intentions to affiliate with chemical engineering in the course? How did recognition beliefs affect these intentions?

Theoretical Framework

We used the engineering role identity framework [14] based on initial STEM role identity work [15], [16] to ground this study. Engineering role identity describes the ways someone dynamically sees themselves as an engineer in each context and is described by three key constructs: recognition beliefs that other people see them as an "engineering person" (e.g., friends, family, self, etc.), interest in engineering, and the beliefs about the ability to understand (competence) and do well (performance) in the area. This work focuses on recognition due to its salience in developing engineering identity in students and predictive power on determining student retention in engineering [13].

Recognition beliefs include how students recognize the self as someone who is able or on the path to becoming an engineer and how they perceive that others see them as engineers or engineering people. Recognition beliefs are developed through explicit recognition, such as direct comments about a student's role as an engineer, or implicit recognition such as indirect actions or treatment that positions a student as an engineer. Students may not perceive all instances that they are being seen as engineers by recognition sources and all perceived recognition may not ultimately be interpreted as meaningful. Meaningful recognition describes recognition that supports or develops an engineering identity and comes from others important in a student's academic life [17], [18]. Whether someone is a meaningful other varies from person to person, but typically includes people close to the student, such as parents, friends, or mentors. How recognition is interpreted or internalized towards identity development is an individual and internal process that is not the focus of this work [17]. Instead, we acknowledge the power and role of meaningful recognition on identity development and the variance in how it is experienced by different students in different contexts.

Methods

This study is part of a larger one investigating multiple aspects of how this course redesign influenced students' beliefs and outcomes. We focus on recognition here as it is an integral part of engineering role identity development but requires a deeper contextual understanding to see how it emerges in practice (e.g., the classroom, lab settings, etc.). None of the course design choices were made solely for the reason of improving recognition and were implemented to benefit student learning and development as a whole.

We utilized a concurrent triangulation mixed methods study design. A quantitative survey measuring engineering role identity (Cronbach's alpha = 0.943) [14], among other factors, was administered at the beginning and end of the course. The surveys were followed by semi-structured interviews of six students from the course focusing on motivations for choosing engineering as a major, their experiences in the course, and how the course affected their beliefs. The qualitative and quantitative results were then mixed using a concurrent triangulation approach [19] utilizing the findings from each stream to corroborate and expand on results seen in both qualitative and quantitative findings. This process is done by comparing the recognition measures from the quantitative findings with the recognition experiences reported in the qualitative findings to develop a validated, solidified picture of first-year undergraduate students' recognition sources and experiences in the redesigned course.

Institutional Context and Participants

The course redesign took place at a large, private university in the Northeastern United States. The course was an introductory undergraduate chemical engineering course of study open to all first-year engineering students, serving as the first chemical engineering experience available at the institution. The course was one of many introductory course options that would count toward any engineering degree and was not required for the chemical engineering major. The course was implemented in Fall 2023 with 48 students initially enrolling, one graduate teaching assistant, and three undergraduate teaching assistants.

Course Design

The redesigned course consisted of two 50-minute lecture periods and one 110-minute discussion section per week. Half of the discussion sections were used as drop-in help hours, while the other half was used for hands-on labs. All content taught in the course utilized food examples and discussed topics including reactive and non-reactive mass balances, vapor-liquid equilibrium, energy balances, engineering design, separations, and safety practices. The course utilized a mastery-based grading scheme, where all problems were directly linked to course learning objectives. Assignments were graded on a scale of Well-Developed, Developing (minor conceptual errors), Under Developed (major conceptual errors), and No Evidence (if insufficient work was done to assess understanding). For assignments using this grading scheme, students could revise their homework and design milestone submissions within a week of receiving feedback with a required reflection on what the specific conceptual error was and how to address that error in future work. Two sets of summative assignments were given: 1) a preliminary exam of the core concepts taught in the semester and 2) the final design report. Only Well-Developed scores were used to demonstrate an understanding of the core course learning objectives. In other words, there was no partial credit in the course.

At the end of the term, students were asked to reflect on their demonstrated understanding of the course learning objectives and to use a guideline for "grade bins" (i.e., what constituted the minimum requirements for A, B, C, D, and F grade in the course) to propose a final grade. Students who proposed final grades outside of the grade bin guidelines were required to provide a reflection that included evidence of how they demonstrated the specific learning objectives in other ways in the course. Any mismatches in student proposal and instructor agreement on final grades were discussed in a virtual 10-minute meeting. Only 9 of 48 students required this meeting, while all other students accurately proposed their grades.

Data Collection and Analysis

A total of 46 engineering students participated in both surveys administered in the course, one on the first day of the course and the other during the last week of the course. We examined the recognition beliefs as part of a larger engineering identity survey (Cronbach's alpha = 0.943) [14]. Only surveys with paired responses in the pre/post data were used in the analysis, leaving 42 complete responses. We checked for normality of the data using q-q plots and evaluating skewness and kurtosis. The results indicated that the data were sufficiently normal for subsequent statistical tests. We used a paired Mann-Whitney U test to evaluate if there were significant differences in the recognition measure across the semester. Cohen's d was used to calculate effect size, and error values were evaluated using the standard error of the mean.

All students were invited to participate in a one-hour semi-structured interview at the conclusion of the course. The interview included discussions about (1) motivations to attend university and consider a major in chemical engineering; (2) experiences in and thoughts about the course and what aspects of it were disliked or liked; and (3) how the course affected their beliefs and identity as a chemical engineer. In particular, we asked students about any moments throughout the course where they felt recognized as a chemical engineer or capable of doing chemical engineering. The list of participants is shown in Table 1. The interviews were transcribed verbatim using Otter.ai and were checked for quality and accuracy by a member of the research team. Interview transcripts were coded in a two-cycle approach. The first pass of coding used a structural coding approach that divided the transcript into the three main sections highlighted above. The second pass used an axial coding approach organizing findings from the first pass into broader themes. For example, initial first-pass codes related to general recognition in engineering were expanded upon into more nuanced reasons for feeling recognized as a chemical engineer, such as being recognized by mentors or peers [20]. The quantitative and qualitative strands of data were then mixed by first using each stream to corroborate the other's findings and then providing specific examples from the qualitative strand for the general trends observed in the quantitative strand. This mixing allows us to report general findings in the class and specific factors for students pushed into or pulled out of the major. All data procedures were approved by the IRB under protocol IRB0148096

Table 1: Participant list and their genders for the semi-structured interviews.

Pseudonym	Gender
Zahir	Man
Vanessa	Woman
Jonathan	Man
Emma	Nonbinary
Grace	Woman
Penelope	Woman

Positionality Statements

Author 1 has an undergraduate and master's degree in chemical engineering. He was not involved with the course until the data analysis began after the course's conclusion. This was Author 1's first experience with course redesign research and he was cautious with how the data was handled and interpreted throughout the process, frequently consulting the other authors to ensure consensus.

Author 2 has a Ph.D. in engineering education and an undergraduate degree in chemical engineering. She co-taught the course with Author 3 during the Fall 2023 term and was responsible for creating the original proposal to the College Center for Teaching and Learning that supported the redesign effort. She collaborated with Author 3 to develop the content, assessment, and pedagogy for the course as the supervising faculty instructor in a mentoring role with a postdoctoral instructor. This redesign effort was her first foray into alternative assessment practices, and she was both excited and apprehensive about how the semester would go. She has integrated hands-on and active learning efforts in first-year engineering, chemical engineering, and graduate coursework. Author 2 brings her knowledge about engineering education research and her interest in identity, motivation, and belonging in student learning, success, and pathways to her instruction. Her teaching philosophy emphasizes a constructivist approach to learning, or that students develop their own understanding and knowledge of the world through their experiences and reflection on those experiences. She views students as active co-constructors of knowledge in the classroom and works to foster a dynamic exchange of knowledge. She views her role as the instructor as one who models learning (both successes and failures) to students and supports the process of reflection on how new material connects to previous knowledge.

The role of Author 3 in course development and instruction is detailed above and he shares the teaching philosophy described by Author 2. Author 3 has a Ph.D. in chemical and biomolecular engineering and an undergraduate degree in chemical and biological engineering. This was also Author 3's first experience with alternative assessment and he approached the redesigned course with significant optimism. Due to the collaboration with Author 2 who was also his postdoctoral mentor, his approach to teaching in this course and the role of the instructor was modeled after that of Author 2.

Results

The results emphasize that recognition improved for all students by a statistically significant amount and medium-to-large effect sizes, with higher gains for women. There were three common sources of recognition students described: 1) recognition by peers, 2) self-recognition, and 3) recognition by mentors. We discuss the results for RQ1 and RQ2 by the quantitative and qualitative data strands, respectively, below.

RQ1: How did student recognition beliefs change throughout the course?

Figure 1 summarizes the average recognition values of the 42 students sampled before and after the course and the computed standard errors of the mean (SEM), Cohen's *d* values, and significance test results. When comparing the average results, we found that recognition as engineering students increased by nearly 25% when comparing results before and after the course, showing substantial promise for the course redesign. This difference is statistically significant ($p < 0.00001$) with medium-large effects ($d = 0.62$). Disaggregating by gender, women experienced a larger increase in recognition ($p < 0.001$, $d = 0.76$) than their men peers ($p < 0.05$, $d = 0.40$) with the introduction of this course redesign (Figure 2). While these results are promising in the positive impact for all students, particularly women, these results may be influenced by the gender makeup of the course, which consisted of more women than men (25 women, 16 men, and 1 non-binary student). We would have liked to also disaggregate the data by other demographics like race/ethnicity and first-generation college student status to understand if the positive effects of the course on recognition beliefs were equitably experienced; however, the sample sizes did not allow for this analysis.

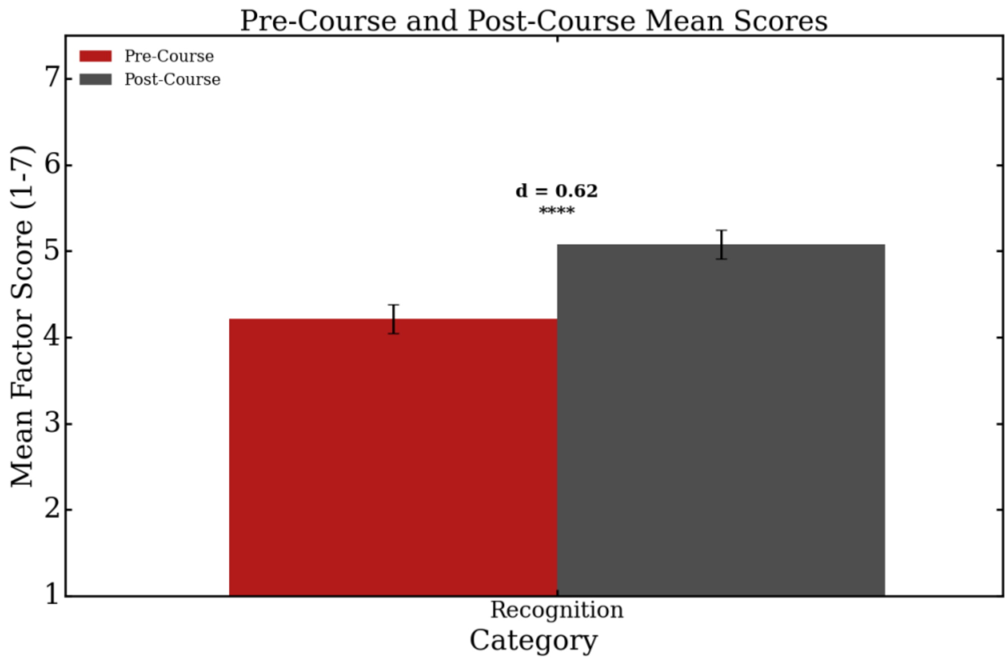

*Figure 1: Average recognition values from before and after the course (n=42). Note: * = p < 0.05, ** = p < 0.01, *** = p < 0.001. Cohen's d is the effect size of estimate with values of 0.2, 0.5, and 0.8 representing small, medium and large effects*

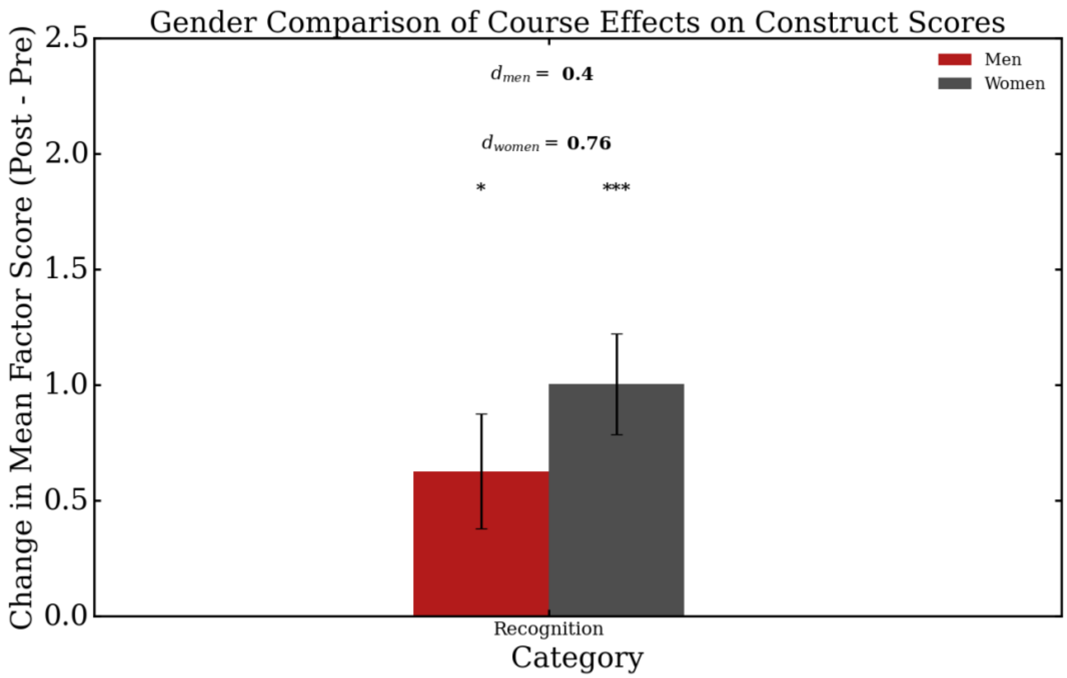

*Figure 2: Average change in recognition between the course's beginning and conclusion (n=42). Note: * = p < 0.05, ** = p < 0.01, *** = p < 0.001. Cohen's d is the effect size of estimate with values of 0.2, 0.5, and 0.8 representing small, medium and large effects*

RQ2: What sources of recognition beliefs emerged throughout the course as important in student experiences?

While the survey responses demonstrated increased feelings of recognition following the course, student interviews provided further detail regarding the sources of recognition observed by the students throughout the course's duration. Across the six interviews conducted regarding the course and its effects, we found three common sources of recognition that emerged in varying forms. While these forms of recognition were not uniformly expressed across each participant, these forms of recognition emerged consistently in at least 2-3 interviewed students.

Recognition by Peers

The most unanimously discussed form of recognition that emerged across the six interviews was recognition by peers, which we generally defined to include fellow students in the course and general university students. We found that peer recognition varied greatly in how students described the phenomenon and its effect on the student. For example, many students within the course felt supported by their peers during in-course activities, as highlighted by Grace:

> I guess when I was working on the design project, and I would get feedback from my teammates. I felt recognized then because they acknowledged how much work I was

> doing, because the thing was… the [design project peer feedback survey] was anonymous. Like, they could have said, whatever but they decided to compliment me in my work, which kind of made me feel acknowledged.

Here, Grace discussed how the in-class project provided her with a chance to be commended by her peers for her contributions to it, providing her with positive feedback and reinforcing her identity stance as an engineering student. Likewise, Jonathan highlighted a more humorous example of recognition from his peers focusing on a more generalized scope of his major:

> Um, I guess, in like social circles, it's like, they use it in like, a joking manner. Like, when you have that one friend who's in pre-med, and then someone is bleeding at a party or something, he's like "pre-med major, come over here. You got this man." It's more like when my roommate goes 'I need chemistry help on a problem.' He's like, "You're a chemical engineer. C'mere, you can solve this for me or you can help me out on this." It's sort of like that.

Jonathan provided an example of peer recognition from peers external to engineering who identified him as a chemical engineer. His peers associated his chemical engineering major with chemistry expertise, and they asked him for help based on this perceived skill set. While the nature of this feedback was supportive, many students actively experienced negative forms of recognition from their peers from outside of the course and the major. Jonathan highlighted the duality of this peer recognition, discussing how peers outside of chemical engineering perceived his choice of major.

> I think it's very interesting to talk to other people who are not in chemical engineering. Just even saying "Oh, I'm doing chemical engineering", and I've never heard of someone go like, "Oh, that's great". They always grimace or say it like "Oh, good luck with that". It's almost like scary, because it doesn't seem so bad right now. But there's so many people that just like hear it and are not very amused by the major, which is pretty frightening. But I assume I'll understand what that comes from. And I hope they're not true about [chemical engineering]… It's more like "Oh, like this class is hard." That's why chemical engineering is hard. I hope it's different.

Jonathan's experience provided an emergent negative experience of recognition related to commonly held stereotypes about what it means to be a chemical engineer. Jonathan's peers offered negative feedback explicitly and more implicitly (body language and facial expressions), highlighting a reputation that the major was particularly difficult or demanding. This experience caused Jonathan to evaluate his interest in a chemical engineering major and consider the stereotypical characterizations of chemical engineering are true. Jonathan's peers implied that Jonathan might not be able to handle the challenge associated with chemical engineering and that his choice may not be wise. Unfortunately, this experience was not unique to Jonathan; it emerged across several other interviewees. For example, Vanessa highlighted another interaction with a peer external to chemical engineering: "But then every time I talk to someone, they're like 'you're doing chemical engineering? that's really hard.' And then that freaks me out. So, then I have like CS in my head as a little backup plan." Here, Vanessa discussed a similar situation to Jonathan's, where a student told her about the difficulty of chemical engineering, causing her to panic and even doubt whether she should remain in chemical engineering, pushing her to consider computer science as an alternative major. Similarly, Emma shared a set of experiences with her peers:

> And some people were like "Wow I feel bad for you." and some are just like "Um...". It's weird that the major has the recognition that it does because as a first year engineering student, like you're not taking anything wildly different from any other engineer. So it's kind of weird in that sense.

Emma's experiences corroborated Vanessa's and Jonathan's, demonstrating this negative recognition associated with chemical engineering. While chemical engineering may pride itself on an emphasis on fundamentals and rigor, these negative recognition experiences may have significant detrimental consequences to student recruitment and retention in the major, as well as role identity development in chemical engineering, if they are not carefully addressed. As students are navigating their emerging identities as chemical engineers, the larger stereotypes about chemical engineering may be an important factor to consider in student interest in and pursuit of a chemical engineering major.

Recognition by Self (Self-Recognition)

Many students discussed moments where they internally recognized themselves as capable chemical engineering students. In contrast to peer recognition, which often happened outside and inside the classroom, these moments of self-recognition solely emerged in the classroom and often in proximity to major assessment milestones like the course project. For example, Vanessa and Penelope were prompted to discuss moments of recognition in the course and both discussed how the course project allowed them to feel some level of self-recognition:

> Um… so again, like through the design project, like being able to sit down, take a prompt, and being able to design something. I feel that process for something that develops something. I think that kind of made me feel like a chemical engineer in a way and like maybe see myself being one in the future. – Vanessa

> Um, I think… over the course of our final project, that's when I felt that "Wow, I could really do this". Because... our team, or I think this applies to all the teams, I think everyone was pretty much like unfamiliar with our teammates, because they were randomized. So being able to kind of go from almost complete strangers to a cohesive team and not just a group of people who work together, but now a team that kind of was able to communicate well and work towards the same thing, and kind of think in stride with one another. That was really, really cool. - Penelope

Both students provided a snapshot of how this course project supports their self-perception as chemical engineers by providing them with the hands-on experience of going through the engineering design cycle from initial research to implementation to redesign while concurrently applying the fundamental principles they learned in the course. The design project provided an opportunity for students, as Penelope mentioned, to see that they can "really do [chemical engineering]”. Similarly, Jonathan and Vanessa echoed a more general sentiment about feeling recognized in the major:

> So it was natural at a certain point in the semester be like “Am I supposed to be here?”. Like, there are people that, at least to me, seemed way better than than me at certain things. But I do think that my mentality of who is smart, who's supposed to be doing this, has changed. It's more like anyone can really do it. Just be passionate about it; do more work, put in the correct amount of work, and it will show so I think as long as I keep working, I do belong in chemical engineering. – Jonathan

> I guess one big takeaway [from the course] is like, I can be a chemical engineer, like in the sense that like, Okay, I was able to do this class and not, like, drop it in the first week, because I didn't know what I was doing. And, like, if I could survive this, then I can probably survive like chemical engineering at Cornell. So I think the takeaway was kind of just like more confidence. - Vanessa

Here, Jonathan highlighted doubts about his performance and competence beliefs when he felt that others in the course knew more than he did; however, he still felt like a chemical engineer as he could complete the required work. Likewise, Vanessa explicitly stated that the course allowed her to believe in herself by showing her that she can complete chemical engineering work. Ultimately, while challenging, this experience gave her confidence in chemical engineering and ultimately, self-recognition as a chemical engineer.

Recognition by Mentors

Students also discussed opportunities where they felt recognized by mentors, which included teaching assistants (TAs) or course instructors. This recognition source can be seen in the context of the high-stakes assessments in the course, such as the course exam and project, which both Zahir and Vanessa discuss respectively:

> Well, after the first prelim I had some doubts. But I spoke to the professor afterwards and she told me that I did really well on the prelim. And we had a conversation about what I was going to do as a major afterwards and she was somewhat disappointed that I wasn't going to stay in chemical engineering. But at that point, I think that's definitely a moment where I did feel recognized as a chemical engineering student. That did lead to me considering it more as a major. Because I did understand the content pretty well. I think that's one of the main experiences. – Zahir

> Yeah so we designed our process, we made posters for it. The professors went around and we were explaining our processes to everyone. And I think because we designed it, and it was something that we made and executed and it was like a chemical engineering-based projects, explaining that and knowing what I was talking about…that made me feel like a chemical engineer – Vanessa

Both Zahir and Vanessa discussed how key mentor interactions in the course help with feeling like a chemical engineering student. Zahir mentioned that his interaction with the instructor after a difficult exam reassured him that he performed well on the exam. Zahir even recalled the instructor expressing disappointment that he was not planning to continue in the major, citing his high level of performance at that point. Despite his plans to not affiliate with chemical engineering, this experience helped Zahir feel recognized as a chemical engineering student and as someone who could succeed in engineering more broadly. Similarly, Vanessa was recognized by the chemical engineering faculty in the department when she presented her final design project for the course. She acknowledged how the design project gave her group a chance to implement chemical engineering knowledge, culminating in presenting her findings. Vanessa's ability to "...[know] what I was talking about" allowed her to be recognized as a chemical engineering student. All in all, these quotes support the quantitative results found earlier, as the increase in recognition by the course's end was detailed through these experiences.

Discussion

This concurrent triangulation mixed methods study demonstrates the notable impact this redesigned course had on feelings of recognition in first-year engineering students, providing evidence for the benefit of this course structure. Specific classroom activities or interactions that positively influenced recognition are discussed in more detail below. The main instances that promoted student recognition in the classroom included the use of a final course project on a chemical engineering process, as this experience allowed students to demonstrate that they can understand and explain complex engineering topics. The course project also provided them with exposure to positive feedback and motivation from mentors, including the instructors, and their own project groups with the use of anonymous peer feedback.

RQ3: What were the push and pull factors associated with students' intentions to affiliate with chemical engineering in the course? How did recognition beliefs affect these intentions?

We first note the significant difference in recognition shown from the course's beginning and end, which provides evidence of the course's success in developing engineering identity in students. Of the three engineering identity constructs studied, recognition beliefs had the largest increase. This result provides evidence that the course redesign provided specific opportunities to offer moments of recognition as chemical engineers for the students, thus bolstering the development of their engineering identities. The course redesign was particularly supportive of women's feelings of recognition, which may be a way to address the continued trends of marginalization and underrepresentation of women in engineering [21], [22]. The exact reason for this larger increase in women is unknown, but some connections with role model effects could be explored with a woman engineering instructor [23], [24]. Other reasons may be that the classroom assessment structure provided a strong emphasis on learning from mistakes and created a nurturing environment different from traditional high-stakes assessments, which have been shown to increase women's test anxiety and reduce performance outcomes [25], [26]. Nonetheless, we stress the impact of this course design on helping students feel more recognized at a crucial point in engineering identity development.

The qualitative data provided an in-depth glimpse of key moments of recognition within this introductory course. Generally, the most persistent and salient recognition forms for these students came from peer interactions, in-class experiences, and mentor interactions. In-class experiences and mentor interactions were exclusively beneficial to students, providing concrete examples of when students demonstrated competence or interest in chemical engineering topics. This trend was not the case for peer recognition, which was shown to be more mixed in its perceived effects; peer interactions had both positive effects, such as Grace's experience with peer evaluation, and negative effects, such as the experiences Emma and Jonathan had in peer's reactions to chemical engineering. The negative part of peer recognition, or negative recognition, is discussed more below but provides a concerning case of how recognition may be limited for chemical engineering students from peers outside of their major.

Negative Recognition of Chemical Engineering

While our quantitative instrument focuses only on positive recognition of common meaningful others, validating students being chemical engineers, the qualitative findings provided insight into the stigmas attached to chemical engineering as a major that may result in negative recognition experiences. Over half of the interviewed students discussed negative views of chemical engineering from peers external to the major, primarily focusing on the difficulty associated with the major. This result aligns with recent literature that discusses the view that college students, in general, often hold chemical engineering as one of the most difficult majors in university [27]. This perception of difficulty and stigmatized views on failure [28] yields an unsavory perception of the major that is perpetuated throughout universities and generations of students. These perceptions may be a part of the declining enrollment rates in chemical engineering nationally as students are more focused on evaluating their stress and workload versus outcomes in career choices [29]. Our qualitative data captures some of this problem, showing how first-year students only taking an introductory chemical engineering course are already fearful of the major even before enrolling. For example, students like Vanessa already made backup plans if chemical engineering was too challenging. The social stigma discussed by Vanessa and Jonathan and the intimidating nature of the curriculum design highlighted by Emma paints a worrying picture for any college student interested in chemical engineering and department administrators who wish to recruit students to major in chemical engineering. Students interested in chemical engineering may have to navigate negative feedback about their choice of major from peers external to the major throughout their first year at university, a time which can be very stressful for many students. This peer discussion about the major's difficulty can also imply that students are not able to handle such a challenging major, ultimately causing students to doubt their place in chemical engineering and making it more likely for them to consider leaving the major, especially when experiencing critical events like poor performance on an exam. This reality is also alarming since many of the students interviewed expressed a deep interest in chemical engineering, such as Jonathan's interest in working with biomolecules. Despite this deep interest, he was still concerned with negative comments, showing the level of impact these can have on even more motivated students. If students who identify closely with chemical engineering are able to be affected by negative recognition, students with weaker ties will likely be even more strongly affected and, thus, be more likely to leave the major. Ultimately, negative recognition is an area that emerged in this work and needs further research attention.

A Push and Pull in Chemical Engineering

Mixing of the qualitative and quantitative data demonstrates a struggling force balance for students interested in chemical engineering as they go through the course. Students receive strong pulls into chemical engineering as they go through the course, receiving opportunities and chances to be recognized by peers or mentors in high-stakes assessments such as the course project or labs while also supporting and recognizing the efforts that their peers are putting in. However, this pull competes against other negative recognition messaging that may pull students away from the major. These peer interactions make the students feel nervous and doubtful that they can manage the coursework without sacrificing other interests, hobbies, or goals. This dissonance in engineering identity development has potential consequences, including hindering identity development or even entirely stopping development if the students choose to avoid associating with chemical engineering and choose a backup plan, as Vanessa alluded. This push force seems to be constant within the major as a whole and not directly affected by the presence of the course. Nonetheless, the course can provide a strong positive pull mechanism into the major by opening up opportunities for students to feel recognized as chemical engineers and develop their engineering identity while enduring that negative recognition from external sources. This force balance also brings back the discussion of the meaningfulness of the source of recognition. Students who value the voice of their peers as more meaningful than mentors or themselves are expected to be more likely to be pulled out of the major due to the internalization of negative recognition. Recognition from this class ultimately impacts this push/pull dynamic by increasing the push factors into the major and providing students with the proof they need to persist in the major, counteracting this looming pull generated by negative recognition.

Limitations and Future Directions

The use of a mixed methods approach provided this study with a deep understanding of the effects this course had on recognition and engineering identity development in students. However, several aspects of this study were limited. First, we do not have access to any quantitative data from previous instances of the course, so we cannot make any claims regarding the effectiveness of this redesigned course structure compared to the traditional offering. Numerous other studies support the benefit of redesigning content, assessment, or pedagogy individually [9], [10], but there has been no work examining impacts when they are combined. The fully redesigned course structure and findings from this study show the benefits of full course redesign through the substantial increase in recognition throughout the course.

However, there are limitations to this study that need to be discussed. While our findings reflect a large increase in feelings of recognition for women, our sample did not allow for disaggregating these changes for other groups of similarly marginalized engineering students. Given that over 90% of the course was an overrepresented group in engineering by race, our sample size for any other marginalized group was grossly insufficient for statistically meaningful results. Future work will benefit from examining if this trend remains similar for other marginalized groups. Similarly, a larger number of interview participants would provide additional support for the themes discussed in this work. In particular, more examples of recognition from mentors would provide evidence for what instructors can implement in classroom contexts to provide recognition.

The quantitative tool derived from [14] provides a valuable way to quantitatively measure recognition using only a few questions, but this measure is typically associated with only the positive recognition sources. Expanding this model to include questions regarding negative recognition would be valuable to see the exact effect it has on engineering identity development, as it is unclear how much, if at all, it would influence identity development.

Conclusions

We relied on previous identity frameworks [14], [15], [16] to guide the methods for this mixed methods study. Quantitative results indicate that the redesigned course structure significantly increased students' feelings of recognition, especially for women. Qualitative results provide a nuanced glance into these trends and show the sources of and impacts of recognition experiences. We found relevant peer-to-peer interactions throughout the class's duration, mentor interactions to ensure success in the course, and high-value assessments to allow students to recognize themselves as being capable of engineering to be the most prevalent examples. These two results, when mixed, provide a push-and-pull dynamic for students interested in the major. Students who feel encouraged or recognized by peers or mentors are pulled into the major but experience pushing factors that keep them away, particularly instances of negative recognition associated with negative perceptions of chemical engineering. These results provide a basis for the benefits of novel course designs in fostering recognition and identity development in first-year students while highlighting the looming negative stigma associated with the field.

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References

[1] R. M. Vasconcelos and L. S. Almeida, "Academic Expectations for Engineering Freshmen: Gender Differences," in *2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, Wollongong, NSW: IEEE, Dec. 2018, pp. 716–719. doi: 10.1109/TALE.2018.8615271.

[2] I. Ngambeki, O. Dalrymple, and D. Evangelou, "Decision Making In First Year Engineering: Exploring How Students Decide About Future Studies And Career Pathways," in *2008 Annual Conference & Exposition Proceedings*, Pittsburgh, Pennsylvania: ASEE Conferences, Jun. 2008, p. 13.351.1-13.351.12. doi: 10.18260/1-2--4247.

[3] J. Sperling, M. Mburi, M. Gray, L. Schmid, and A. Saterbak, "Effects of a first-year undergraduate engineering design course: survey study of implications for student self-efficacy and professional skills, with focus on gender/sex and race/ethnicity," *IJ STEM Ed*, vol. 11, no. 1, p. 8, Feb. 2024, doi: 10.1186/s40594-024-00467-6.

[4] J. R. Power, D. Tanner, and J. Buckley, "Self-efficacy development in undergraduate engineering education," *European Journal of Engineering Education*, pp. 1–25, Jul. 2024, doi: 10.1080/03043797.2024.2368149.

[5] P. C. Wankat and F. S. Oreovicz, *Teaching Engineering, Second Edition*. Purdue University Press, 2015. doi: 10.2307/j.ctv15wxqn9.

[6] Felder, Richard M. and Brent, Rebecca, *Teaching and Learning STEM: A Practical Guide*. Hoboken, NJ: Jossey-Bass/Wiley, 2024.

[7] A. Malespina, C. D. Schunn, and C. Singh, "Whose ability and growth matter? Gender, mindset and performance in physics," *IJ STEM Ed*, vol. 9, no. 1, p. 28, Dec. 2022, doi: 10.1186/s40594-022-00342-2.

[8] J. E. Froyd, P. C. Wankat, and K. A. Smith, "Five Major Shifts in 100 Years of Engineering Education," *Proc. IEEE*, vol. 100, no. Special Centennial Issue, pp. 1344–1360, May 2012, doi: 10.1109/JPROC.2012.2190167.

[9] S. Freeman *et al.*, "Active learning increases student performance in science, engineering, and mathematics," *Proc. Natl. Acad. Sci. U.S.A.*, vol. 111, no. 23, pp. 8410–8415, Jun. 2014, doi: 10.1073/pnas.1319030111.

[10] L. Landherr, "Ungrading in Chemical Engineering: Attempting to Eliminate Exams, Deadlines, and Anxiety by Refocusing on Learning Instead of Grades," in *2023 ASEE Annual Conference & Exposition Proceedings*, Baltimore , Maryland: ASEE Conferences, Jun. 2023, p. 44552. doi: 10.18260/1-2--44552.

[11] Vigeant, Margot A. and Jenkins, Kendall, "Temper, Temper," *CEE*, vol. 58, no. 4, Sep. 2024.

[12] B. Hughes, W. Schell, B. Tallman, R. Beigel, E. Annand, and M. Kwapisz, "Do I Think I'm an Engineer? Understanding the Impact of Engineering Identity on Retention," in *2019 ASEE Annual Conference & Exposition Proceedings*, Tampa, Florida: ASEE Conferences, Jun. 2019, p. 32674. doi: 10.18260/1-2--32674.

[13] A. Godwin, G. Potvin, Z. Hazari, and R. Lock, "Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice," *J of Engineering Edu*, vol. 105, no. 2, pp. 312–340, Apr. 2016, doi: 10.1002/jee.20118.

[14] A. Godwin, "The Development of a Measure of Engineering Identity," in *2016 ASEE Annual Conference & Exposition Proceedings*, New Orleans, Louisiana: ASEE Conferences, Jun. 2016, p. 26122. doi: 10.18260/p.26122.

[15] H. B. Carlone and A. Johnson, "Understanding the science experiences of successful women of color: Science identity as an analytic lens," *J Res Sci Teach*, vol. 44, no. 8, pp. 1187–1218, Oct. 2007, doi: 10.1002/tea.20237.

[16] Z. Hazari, G. Sonnert, P. M. Sadler, and M. Shanahan, "Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study," *J Res Sci Teach*, vol. 47, no. 8, pp. 978–1003, Oct. 2010, doi: 10.1002/tea.20363.

[17] K. Scalaro, I. Chatterjee, A.-M. Vollstedt, J. LaCombe, and A. Kirn, "A Two-step Model for the Interpretation of Meaningful Recognition," in *2021 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual Conference: ASEE Conferences, Jul. 2021, p. 36626. doi: 10.18260/1-2--36626.

[18] Z. Hazari, C. Cass, and C. Beattie, “Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development: TEACHER POSITIONING AND STUDENT PHYSICS IDENTITY,” *J Res Sci Teach*, vol. 52, no. 6, pp. 735–762, Aug. 2015, doi: 10.1002/tea.21214.

[19] R. B. Johnson and A. J. Onwuegbuzie, “Mixed Methods Research: A Research Paradigm Whose Time Has Come,” *Educational Researcher*, vol. 33, no. 7, pp. 14–26, Oct. 2004, doi: 10.3102/0013189X033007014.

[20] J. Saldaña, *The coding manual for qualitative researchers*, 2. ed. Los Angeles, Calif.: SAGE Publ, 2013.

[21] R. M. Marra, K. A. Rodgers, D. Shen, and B. Bogue, “Leaving Engineering: A Multi-Year Single Institution Study,” *J of Engineering Edu*, vol. 101, no. 1, pp. 6–27, Jan. 2012, doi: 10.1002/j.2168-9830.2012.tb00039.x.

[22] E. Seymour and A.-B. Hunter, Eds., *Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*. Cham: Springer International Publishing, 2019. doi: 10.1007/978-3-030-25304-2.

[23] J. R. Gladstone and A. Cimpian, “Which role models are effective for which students? A systematic review and four recommendations for maximizing the effectiveness of role models in STEM,” *IJ STEM Ed*, vol. 8, no. 1, p. 59, Dec. 2021, doi: 10.1186/s40594-021-00315-x.

[24] Y. M. Bamberger, “Encouraging Girls into Science and Technology with Feminine Role Model: Does This Work?,” *J Sci Educ Technol*, vol. 23, no. 4, pp. 549–561, Aug. 2014, doi: 10.1007/s10956-014-9487-7.

[25] E. M. Marshman, Z. Y. Kalender, T. Nokes-Malach, C. Schunn, and C. Singh, “Female students with A’s have similar physics self-efficacy as male students with C’s in introductory courses: A cause for alarm?,” *Phys. Rev. Phys. Educ. Res.*, vol. 14, no. 2, p. 020123, Dec. 2018, doi: 10.1103/PhysRevPhysEducRes.14.020123.

[26] J. Major, M. Scheidt, A. Godwin, E. Berger, and J. Chen, “Effects of Test Anxiety on Engineering Students’ STEM Success,” in *2020 ASEE Virtual Annual Conference Content Access Proceedings*, Virtual On line: ASEE Conferences, Jun. 2020, p. 34511. doi: 10.18260/1-2--34511.

[27] V. Novik, “The Role of Learning in Returns to College Major: Evidence from 2.8 Million Reviews of 150,000 Professors,” *SSRN Journal*, 2022, doi: 10.2139/ssrn.4275668.

[28] A. Simpson and A. Maltese, “‘Failure Is a Major Component of Learning Anything’: The Role of Failure in the Development of STEM Professionals,” *J Sci Educ Technol*, vol. 26, no. 2, pp. 223–237, Apr. 2017, doi: 10.1007/s10956-016-9674-9.

[29] M. Wiswall and B. Zafar, “New approaches to understanding choice of major,” *National Bureau of Economic Research Reporter*, no. 2, pp. 18–21, 2021.