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Instilling Confidence and Belonging in a First Year Mechanical Engineering Robotics Course

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The aim of this complete evidence-based practice study was for the instructors, and authors, to better understand students' confidence levels and sense of belonging across demographics including gender, first generation status, ethnicity and class standing in an introductory mechanical design course. Undergraduates (N = 93) enrolled in the course in spring 2024 were assigned weekly reflection assignments, graded for on-time completion. A subset of items, repeated each week, asked students to rate their ability to apply a set engineering skills being taught in the course that included computer-aided design, use of hands-on making tools, ability to apply engineering theory to a design project, ability to explain design ideas to other students, and ability to apply engineering theory to a design project. Students were also asked weekly, in the reflection assignments, to rate the extent they felt included and welcomed in the class. Paired t-test analyses were conducted on the reflection data to determine means and possible significance ($p < 0.05$) between students (N = 64) reflection responses early in the quarter-long course and during the final week of instruction. Analysis outcomes confirmed positive and significant gains ($p < 0.05$) for each criterion assessed at the class level (N = 64). Non-significant gains ($p > 0.05$) in students' feelings of belonging were detected in the male (N = 44) and URM (N = 16) demographic groups. The quantitative findings provide a foundation for further investigation into students' sense of belonging, confidence in their engineering skill and academic outcomes.

Introduction

MAE 3 *Introduction to Mechanical Engineering* is a required undergraduate elective offered for the last 20 years by the Mechanical & Aerospace Department (MAE) at UC San Diego. The course provides first-year engineering students with an engaging hands-on learning experience focused on machine design, the engineering design process, computer-aided design (CAD), rapid prototyping and fabrication skills. This course is unique in that students also learn and apply fundamental engineering science concepts to their design projects, alongside developing their hands-on skills.

The physics and engineering design concepts are covered during the twice weekly 90-minute-long active-learning lecture sessions. Students then apply these concepts to two projects during the quarter-long course (i.e., 10 weeks), beginning with an individual clock project followed by a longer team-based robotics project. While successful completion of a calculus-based science-engineering general physics course is required, it is not expected, nor required, that students who register for the course have experience with CAD, engineering design, fabrication or robotics. Indeed, majority of students arrive with little to no hands-on engineering design experience.

During the first three weeks of the quarter, students learn basic CAD skills, metal fabrication techniques and use of the laser cutter in the 3 hour long weekly lab sessions to design, build and analyze a personalized pendulum clock. Midway through the course, after students have acquired the necessary design and fabrication skills, they are presented with a team-based robotic design challenge. The unique thematic robotic challenge is developed by the instructional team each quarter to give students an opportunity to work in teams and to apply their engineering skills to an open-ended challenge. While the competition rules, scoring criteria and project milestones are well-defined, the term specified challenge, and the unique theme adds an element of excitement and an opportunity for the teams to be creative and strategic in their robot design. During finals week, a course-wide robot competition takes place where all teams compete for prizes and recognition such as for innovative design, fabrication achievements and best presentation. The competition event is a high energy celebratory experience open to the public (Fig. 1).

Figure 1. **An MAE 3 Undergraduate Tutor (left) with students (right) and their robot at the course-wide final robot competition.**

Through a process of continuous improvement, the popular course has maintained a mixed reputation among students as “being a lot of work!” and as a valuable high impact learning experience. Students often share with instructors that the course experience provided a solid foundation in essential hands-on engineering skills and prepared them for advanced coursework, engineering clubs, capstone design and technical careers. The course is rich in social relational elements with peer mentors teaching CAD and fabrication skills in the lab sessions, mentoring the student robot teams, and offering support throughout the quarter long course experience. The faculty instructors, graduate teaching assistants and undergraduate tutors work intentionally to ensure that all students receive a welcoming and inclusive learning experience.

The motivation for this study is to better understand students’ experiences in developing confidence in their engineering skills and their sense of belonging in an introductory mechanical design course. The instructors, and authors, were interested in exploring students’ weekly reflection assignments to gain insight into their confidence levels, in terms of the engineering skills being taught in the course, and their sense of belonging in the course, in terms of feeling included and welcomed in the class and lab activities. The secondary aim of this study is to explore and identify differences in students' confidence levels and sense of belonging across demographic groups including gender, first gen status, ethnicity and class standing.

Background

Students in the MAE3 course spend a considerable amount of time interacting with faculty in the interactive lectures and with their undergraduate tutors and peers in the weekly lab sessions. It is not uncommon for students to spend eight hours or more a week outside of the scheduled lab and lecture times, working in the design studio on their hands-on projects and/or attending various office hours. Although students spend significant amounts of time interacting with the instructional team and collaborating with their peers, it was not clear to the instructors, prior to this work, if students in general felt a strong sense of belonging in the course.
A student's sense of belonging is an affective construct that generally refers to their feelings of being accepted, valued, included, and connected to a group based on one's emotional experience within that group [1]. Students' sense of belonging has been shown to influence their academic persistence [2] and motivation [3]. For students with minoritized or marginalized identities a strong sense of belonging contributes to their engineering identity [4]. Likewise, engineering identity can have a direct impact on a student's sense of belonging and persistence of effort, with belonging acting as a mediator. Earlier research on an individual's sense of belonging in engineering revealed positive correlations with their psychological sense of community, technical competence, and feelings of being socially at ease [5]. Within the engineering undergraduate classroom, the direct effects of faculty and peer interaction have been shown to significantly increase students' sense of academic belonging, with peer interaction having the greatest impact [6].

Pedagogical approaches such as active and cooperative learning can also positively impact students' sense of belonging in the classroom [7]. Active learning encompasses a variety of student-centered techniques that improve student engagement, the quality of interpersonal interactions and perceptions of social support that are highly impactful to students' well-being [8]. Cooperative learning is a form of active learning, where students work in teams and are held individually accountable for completing a project or assignment [9]. A growing body of research suggests that these pedagogical approaches can also support student well-being, which encompasses their sense of belonging [10].

The aim of this study is to provide the instructors with a first-pass quantitative understanding of students' sense of belonging in the course and their confidence in the engineering skills they developed and applied to the hands-on active and cooperative learning assignments.

Research Methodology

Undergraduates (N = 93) enrolled in the MAE 3 *Introduction to Mechanical Engineering* course in spring quarter 2024 were assigned weekly reflection assignments, graded for on-time completion. A subset of the weekly reflection items asked students to rate their abilities with engineering skills being taught in the course. These skills include their abilities to (i) use hands-on Making tools, (ii) with computer aided design (CAD), (iii) to use freehand sketching to communicate a design idea, (iv) to explain design ideas to other students, and (v) to apply engineering theory to a design project. Students were also asked to rate (vi) to what extent they felt included and welcome in the class and lab activities.

Analysis of the reflection data involved descriptive quantitative analysis and paired t-tests to determine if there were significant differences in student's self-ratings between the beginning and the end of the quarter for the six criteria listed above. Differences based on demographic characteristics, such as gender and ethnicity and first generation standing were also explored.

The three research questions that this exploratory study aimed to address were:

RQ1: Did student's "confidence" change over the over the quarter-long course experience?
In this study, students' confidence is defined by their self-rated abilities to use hands-on Making tools, with CAD, using freehand sketching to communicate a design idea, ability to explain design ideas to other students, and ability to apply engineering theory to a design project.

RQ2: Did student's sense of belonging, in terms of feeling included and welcomed in the class and lab activities, change over the over the quarter-long course experience?
In this study, students' sense of belonging is defined by the extent of their self-rated feelings of being included and welcomed in the class and lab activities.

RQ3: Did differences in students' confidence and sense of belonging differ among demographic populations based on gender, ethnicity and first-generation status?
In this study, differences in demographic groups were limited to gender, or female/male, ethnicity, or URM/Non URM, and first-generation status.

Findings

Study findings include student demographics (N = 88) in the MAE 3 course in spring quarter 2024. Results of paired t-test analyses feature mean values and determination of significance ($p < 0.05$) between the week two and week nine survey responses for students' (N = 64) sense of belonging and confidence in their engineering skills. Shifts in students' confidence in their engineering skills were analyzed to determine if differences were present based on gender. Finally, an analysis of students' (N = 64) self-rated feelings of belonging was carried out to determine if the shifts between week two and week nine were significant and/or there were differences between selected demographic groups (i.e., gender, ethnicity and first-generation status).

Demographics

In spring 2024, a total of eighty-eight students were enrolled in the MAE 3 course. Between the two course sections, A and B, each led by a different instructor, much of the class was comprised of sophomores (44.3%) and junior (38.6%) students, followed by seniors (17%) and freshmen (10.2%). See Table 1, below, for a breakdown of student enrollment by class standing.

Table 1. Student enrollment (N = 88) in spring 2024 by section and class standing.

Section	Freshmen	Sophomore	Junior	Senior
A (n = 33)	0	11	15	7
B (n = 55)	9	28	10	8
Total Percent	10.2 %	44.3%	38.6%	17.0%

Enrollment by gender was predominately male (73.9%), with only 25% identifying as female and 1% of unknown gender. Student demographics by ethnicity were 22.7% underrepresented minority (URM) and 33% of all students were first-generation (First Gen). Further demographic breakdown highlighted that 17% of the students identified as URM and First Gen, and 8% identified as URM, First Gen and were sophomores.

Given the focus of this study on students' sense of belonging, it was useful to know that a majority had been on campus for less than a year when they took the course, 62.5 % were admitted to the university in Fall 2023.

Changes in Student Confidence

To address research question one (RQ1), matched pairs of students' (N = 64) week two and week nine reflection responses were analyzed. Due to incomplete data sets for both sections of the course, a complete reflection data set was not available for the first week, changes in students' confidence were determined using the data available, week two and week nine. Paired t-tests were conducted on the data sets to determine if there were significant differences ($p < 0.05$) in students self-rating of their engineering skills from early in the quarter, or week two, to the final week of instruction, or week nine. The survey items and rating scale used to answer RQ1 are provided below. Results of the paired t-test analysis are presented in Table 2.

RQ1: Did student's "confidence" change over the over the quarter-long course experience?
Five survey items were used to determine changes in students' self-reported confidence in their engineering skills:

(i) Rate your ability to use hands-on Making tools.

(ii) Rate your ability with Computer Aided Design (CAD).

(iii) Rate your ability to use freehand sketching to communicate design ideas.

(iv) Rate your ability to explain design ideas to other students.

(v) Rate your ability to apply engineering theory to a design project.

The following rating scale and associated research values were used for each item: Very ineffective = 0; Ineffective = 1; Medium = 2; Effective = 3; Very effective = 4. The numerical significance of the p-values in Table 2, Table 3, and Table 4 include a notation for the level of significance as follows; * = 0.05, ** = 0.01, and *** = 0.001.

Further analysis was conducted to address RQ3 and determine if there were significant differences, based on gender, in students' confidence in their engineering skills between the beginning and the end of the quarter. This data set (N = 63) included nineteen females, forty-four males and one student of unknown gender, who's data was not used due to the limited data set

(N =1). Results for the paired t-test analysis on students' self-ratings, by female and male gender, for the five related engineering skills in week two and week nine, are provided in Table 3.

Table 2. Changes in students (N = 64) self-rating of their engineering skills at the beginning and at the end of the quarter.

Reflection Items (N = 64)	**Week 2** Mean Value	**Week 9** Mean Value	**Significance** two tail paired t-test
Ability to Apply Engineering Theory to Design Project	2.14	2.77	***$p = 1.34 \times 10^{-8}$
Ability with Hands-on Making Tools	2.25	3.05	***$p = 5.66 \times 10^{-9}$
Ability with CAD	2.60	2.92	***$p = 6.95 \times 10^{-4}$
Use Freehand Sketching to Communicate a Design Idea	2.52	2.78	**$p = 4.34 \times 10^{-3}$
Explain Design Ideas to Other Students	2.39	2.95	***$p = 6.67 \times 10^{-7}$

Table 3. Changes in students' (N = 63) self-rating of their engineering skills, by gender, at the beginning and at the end of the quarter.

Reflection Items	**Demographic**	**Week 2** Mean Value	**Week 9** Mean Value	**Significance** two tail paired t-test
Ability to Apply Engineering Theory to Design Project	Female (N = 19)	2.21	2.95	***$p = 2 \times 10^{-5}$
	Male (N = 44)	2.09	2.68	***$p = 3.2 \times 10^{-5}$
Ability with Hands-on Making Tools	Female (N = 19)	2.11	3.00	***$p = 3.1 \times 10^{-4}$
	Male (N = 44)	2.32	3.07	***$p = 9.5 \times 10^{-6}$
Ability with CAD	Female (N = 19)	2.47	2.89	*$p = 4.19 \times 10^{-2}$
	Male (N = 44)	2.63	2.93	**$p = 7.75 \times 10^{-3}$
Use Freehand Sketching to Communicate a Design Idea	Female (N = 19)	2.42	2.89	**$p = 3.37 \times 10^{-3}$
	Male (N = 44)	2.55	2.73	$p = 0.118$
Explain Design Ideas to Other Students	Female (N = 19)	2.32	3.05	***$p = 1.1 \times 10^{-4}$
	Male (N = 44)	2.41	2.91	***$p = 4.7 \times 10^{-4}$

Changes in Student Belonging

To address RQ2 and RQ3, matched pairs (N = 64) of students' week two and week nine reflection responses were evaluated. Due to incomplete data sets for both sections of the course, a complete reflection data set was not available for the first week, changes in students' feelings of belonging were determined using the data available (N = 64). Paired t-tests were conducted on the data sets to determine if there were significant differences ($p < 0.05$) in student's self-rating from early in the quarter to the final week of instruction. This data set was further evaluated to determine if there were differences in students' self-ratings based on gender, ethnicity and first-generation status. The survey item and rating scale used to answer RQ2 and RQ3 are provided below. Results of the paired t-test analysis are presented in Table 4.

Table 4. Changes in students' (N=64) self-rating their feelings of belonging at the beginning and at the end of the quarter, by gender, ethnicity and first-generation status.

Extent that you feel welcome and included in the class and lab activities	**Week 2** Mean Value	**Week 9** Mean Value	**Significance** two tail paired t-test
ALL Students (N = 64)	3.00	3.26	**$p = 6.91 \times 10^{-3}$
Female Students (N = 19)	3.05	3.63	**$p = 1.86 \times 10^{-3}$
Male Students (N = 44)	2.98	3.11	$p = 0.244$
URM (N = 16)	2.82	3.12	$p = 0.0861$
Non-URM (N = 46)	3.04	3.3	*$p = 0.0216$
First Gen (N = 22)	2.77	3.09	$p = 0.0896$
Not First Gen (N = 44)	3.12	3.39	*$p = 0.0198$

Shifts in Students' Self-ratings

To gain further insight into the magnitude of the shifts in students' self-ratings for their feelings of belonging and confidence in their engineering skills, the difference, or delta, was calculated between their week nine and their week two ratings. For example, a shift in a student's rating for the "extent that you feel welcome and included in the class and lab activities" as "somewhat included and welcome," with a score = 1 in week two, to "highly included and welcome," with a score = 3 in week nine, would have a positive delta score of 2. The delta values involve a set of whole numbers ranging from (-4, -3, -2, -1, 0, 1, 2, 3, 4), measuring both positive and negative trends. These values were quantified over the paired set (N = 64), see Table 5, and plotted to provide a holistic visual representation of changes in students ratings, see Figure 2.

Review of this data, in Table 5, shows that a relatively small number of students' self-ratings dropped one scale level (i.e., -1) between their week 9 and week two reflection assignments. The criterion with the largest numbers of students who rated one scale level lower in week nine were for their use of freehand sketching to communicate a design idea (N = 8), their feelings of belonging (N =7) and their ability to explain design ideas to other students (N = 7). A sizeable cohort of the class had consistent ratings (i.e., delta = 0) for their sense of belonging (N = 38), their abilities to use CAD (N = 35) and their use of freehand sketching to communicate design ideas (N = 33). Another sizable number of students had positive gains (i.e., delta => 1) in their ability to apply engineering theory to a design project (N = 38), ability to use hands-on Making tools (N = 38) and their ability to explain design ideas to other students (N = 37).

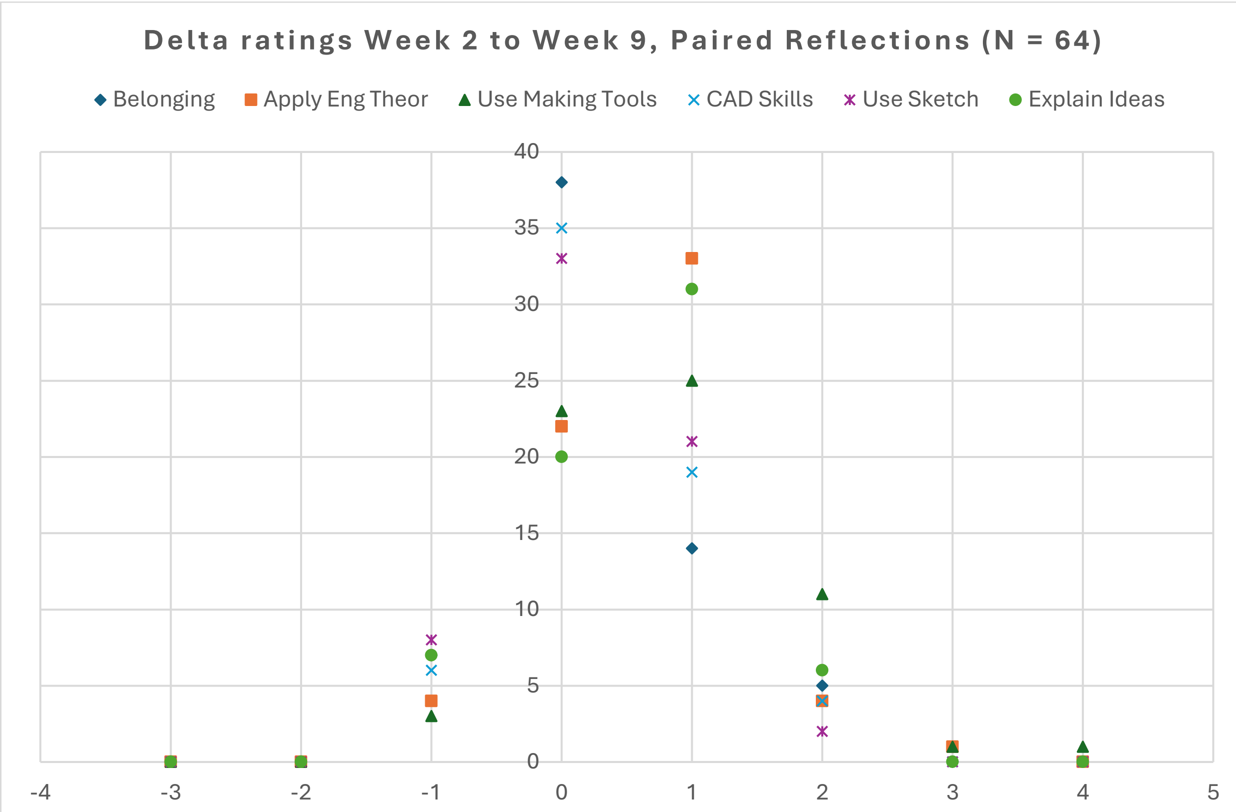

Figure 2. **The plot of shifts in students' (N = 64) paired self-ratings from week two to week nine, the delta represents week nine rating minus their week two rating.**

Table 5. Count of shifts in students' (N = 64) paired self-ratings from week two to week nine, the delta represents their week nine rating minus their week two rating.

delta = W9 - W2	Feelings of Belonging	Apply Engineering Theory	Making Tools	CAD Skills	Use Sketching	Explain Ideas
-3	0	0	0	0	0	0
-2	0	0	0	0	0	0
-1	7	4	3	6	8	7
0	38	22	23	35	33	20
1	14	33	25	19	21	31
2	5	4	11	4	2	6
3	0	1	1	0	0	0
4	0	0	1	0	0	0

Discussion

Given that this course is intended for first year students and is a required elective for the ME major, enrollment demographics indicated a possible trend that students may be taking this course later in their studies. For example, only 10.2 percent of the class were registered freshmen. Class standing can be misleading as many students enroll with significant credits and/or register for high credit hours each quarter. Either of these circumstances would impact a student's class standing. Yet, it is worthwhile noting that 62.5 % of the students enrolled in the spring 2024 course were admitted to the university in Fall 2023, so technically still in their first year on campus.

Gains in students' confidence in their engineering skills were encouraging as there were significant gains ($p < 0.05$) across all five of the engineering skills analyzed: (i) rate your ability to use hands-on Making tools, (ii) rate your ability with Computer Aided Design (CAD), (iii) rate your ability to use freehand sketching to communicate design ideas, (iv) rate your ability to explain design ideas to other students, and (v) rate your ability to apply engineering theory to a design project. Mean scores for students' self-rated engineering skills, relative to others in the class, early in the course (i.e., week 2) ranged from 2.14 for their ability to apply engineering theory to a design project to 2.59 for their CAD skills. These ratings correspond to ranking of Medium = 2 to Effective = 3. At the end of the quarter, in week nine, mean scores for students' ratings of their engineering skills ranged from 2.77 for Ability to Apply Engineering Theory to Design Project to 3.05 for Ability with Hands-on Making Tools, with Very effective = 4. See Table 2.

Overall, the most significant gains were in student's self-rated abilities to apply engineering theory to a design project and to use of hands-on Making tools, with a mean rating in week nine of 3.05 (i.e., Effective = 3 to Very effective = 4). Outcomes for the ensuing analysis on differences in student's self-rated engineering skills by gender indicated that females ($N = 19$) overall made the largest gains between weeks two to week nine with significance ($p < 0.05$) across all five skills. Males ($N = 44$) had significant gains for four of the skills, except in their ability to use freehand sketching to communicate a design idea ($p > 0.05$). See Table 3.

Shifts in students' sense of belonging course wide ($N = 64$) were significantly higher in week nine (Mean = 3.26) than at the beginning of the quarter (Mean = 3) in week two. These values correspond to the rating scale: Highly included and welcome = 3, Very highly included and welcome = 4. It is important to note that the formal add/drop period ended at the end of the second week, therefore it is possible that students who dropped the course may have had lower feelings of belonging. An analysis that explored students' sense of belonging coming into course, during the first week of instruction, would have addressed students' initial experiences with feeling welcomed and included in the class and lab activities.

Further analysis on students' self-rated feelings of belonging by gender, ethnicity and first-generation status provided insight into areas for further consideration. Female students ($N = 19$) reported significantly higher ($p < 0.05$) rates of belonging between weeks two and nine, with respective means of 3.05 and 3.63. While male students ($N = 44$) and underrepresented minority student did not report significant gains ($p > 0.05$) during this same time frame. The mean scores for male student shifted from 2.98 in week two to 3.11 in week nine, for URM students the corresponding means were 2.82 to 3.12 respectively. Although the paired t-test outcomes for first generation students (N = 22) and non-first generation students (N = 41) highlight significant gains ($p < 0.05$) for both groups, the means for First Gen were lower overall in week two (Mean = 2.77) and in week nine (Mean = 3.09) than the class average (N = 64) , with means of 3 and 3.26 respectively. See Table 4.

To gain further insight into shifts in students' self-rating for their engineering skills and feelings of belonging in the course, delta values were calculated for the paired sets of reflection surveys. The delta value was calculated by subtracting a student's rating in week nine from their rating in week two for each criterion. The delta values represent negative (delta = -4, -3, -2, or -1), neutral (delta = 0), and positive shifts (delta = 1, 2, 3, or 4) in a student's paired ratings. The plot (Fig. 2) and accompanying Table 5 provide a data count and visualization of shifts in students (N = 64) self-ratings. Outcomes from the delta analysis bring attention to a small but noteworthy groups of students whose self-rating dropped (delta = -1). For example, eight students rated one scale level lower in week nine than week two for their use of freehand sketching to communicate a design idea, seven for their feelings of belonging and seven on their ability to explain design ideas to other students. A sizeable cohort of the class had consistent ratings (i.e., delta = 0) for their sense of belonging (N = 38), their abilities to use CAD (N = 35) and their use of freehand sketching to communicate design ideas (N = 33).

Review of this data, in Table 5, shows that a relatively small number of students' self-ratings dropped by a one scale level (i.e., -1) between their week 9 and week two reflection assignments. The criterion with the largest numbers of students who rated one scale level lower in week nine were for their use of freehand sketching to communicate a design idea (N = 8), their feelings of belonging (N =7) and their ability to explain design ideas to other students (N = 7). Fifty-nine percent of the class had consistent ratings (i.e., delta = 0) for their sense of belonging (N = 38). Another large percentage of students (> 58%) had positive gains (i.e., delta => 1) in their ability to apply engineering theory to a design project, ability to use hands-on Making tools and their ability to explain design ideas to other students.

Conclusion and Future work

Outcomes of this quantitative analysis provided essential data on students' self-rated confidence in their engineering skills taught in the course and their feelings of being welcomed and included in the class and lab activities. While the paired t-test analyses results confirmed positive and significant gains ($p < 0.05$) for each criterion assessed at the class level (N = 64), analyses performed for various demographics highlighted areas for further investigation. For example, non-significant gains ($p > 0.05$) were detected in the male (N = 44) and URM (N = 16) cohort's feelings of belonging.

Future work will focus on students' sense of belonging across demographics through qualitative and mixed method analyses. This work is essential for making informed decisions on addressing equity gaps in students learning experience improving course curriculum for all students in the MAE 3 course.

References

[1] Allen, K. A., Kern, M. L., Rozek, C. S., McInerney, D. M., & Slavich, G. M. (2021). Belonging: a review of conceptual issues, an integrative framework, and directions for future research. *Australian Journal of Psychology*, 73(1), 87–102. https://doi.org/10.1080/00049530.2021.1883409

[2] Davis, G. M., Hanzsek-Brill, M. B., Petzold, M. C., & Robinson, D. H. (2019). Students' sense of belonging: The development of a predictive retention model. *Journal of the Scholarship of Teaching and Learning*, 19(1). https://doi.org/10.14434/josotl.v19i1.26787

[3] Neel, C. G.-O., & Fuligni, A. (2013). A longitudinal study of school belonging and academic motivation across high school. *Child Development*, 84(2), 678–692. https://doi.org/10.1111/j.1467-8624.2012.01862.x

[4] Patrick, A., Andrews, M., Riegle-Crumb, C., Kendall, M. R., Bachman, J., & Subbian, V. (2023). Sense of belonging in engineering and identity centrality among undergraduate students at Hispanic-Serving Institutions. *Journal of Engineering Education*, *112*(2), 316-336.

[5] Verdín, D., Godwin, A., Kirn, A., Benson, L., & Potvin, G. (2018). Understanding how engineering identity and belongingness predict grit for first-generation college students. In *The Collaborative Network for Engineering and Computing Diversity Conference.*

[6] Wilson, D. M., Bell, P., Jones, D., & Hansen, L. (2010). A cross-sectional study of belonging in engineering communities. *International Journal of Engineering Education*, *26*(3), 687-698.

[7] Polmear, M., Hunsu, N. J., Simmons, D. R., Olaogun, O. P., & Lu, L. (2024). Belonging in engineering: Exploring the predictive relevance of social interaction and individual factors on undergraduate students' belonging in engineering. *Journal of Engineering Education*.

[8] Meeuwisse, M., Severiens, S. E., & Born, M. P. (2010). Learning environment, interaction, sense of belonging and study success in ethnically diverse student groups. *Research in Higher Education*, 51(6), 528–545. https://doi.org/10.1007/s11162-010-9169-1

[9] Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, 93(3), 223-231.

[10] Felder, R. M., & Brent, R. (2007). Cooperative learning. *Active learning: Models from the analytical sciences*, *970*, 34-53.

[11] White, H. C., Allen, D. M., Buffinton, K., Humphrey, D., Malpiede, M., Miller, R. K., & Volin, J. C. (2024). Cultivating long-term well-being through transformative undergraduate education. *PNAS nexus*, *3*(9), p 372.

[12] Fernández, D. P., Ryan, M. K., & Begeny, C. T. (2023). Recognizing the diversity in how students define belonging: evidence of differing conceptualizations, including as a function of students' gender and socioeconomic background. *Social Psychology of Education*, *26*(3), 673-708.