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WIP: A Peer-Taught Course to Lower Barriers to Undergraduate Research Experiences

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Introduction

First-year engineering students experience challenges as they work to build a sense of community [1]. During the period of adjusting to the university environment, students often experience imposter syndrome, feelings of not belonging, and low self-efficacy. These challenges are especially pronounced for first-generation students and members of historically marginalized groups [2].

Undergraduate research experiences represent high-impact experiential learning opportunities that offer numerous benefits, including increased self-efficacy and persistence in their field of study [3], [4], [5]. Additionally, research experiences increase undergraduate students' awareness of and interest in science, technology, engineering, and math (STEM) careers and support students who want to pursue graduate school or work in industry [3]. However, several barriers to entry into undergraduate research experiences exist. Some of these barriers include lack of confidence, uncertainty about how to start, limited guidance, feelings of inadequacy, lack of awareness about research, and lack of representation in research spaces [6]. Virtual workshops and in-person workshops [7], [8] have been offered as a strategy to solve this problem. However, attendance and engagement over time decreased with an extracurricular workshop format [7]. If students are unable to overcome barriers to joining research opportunities, or if they do not persist in their participation in activities that connect them to research opportunities, then the benefits of undergraduate research cannot be achieved.

Students benefit from peer support and mentoring outside the classroom [9], [10]. Peer mentors in research provide socioemotional and cultural support which impacts student development [10]. Peer mentoring is beneficial for first-year engineering students to help increase belonging and social integration [11], [12]. Peer instruction is an evidence-based instructional strategy that leads to increased student mastery of problem-solving and conceptual reasoning [13], [14]. Furthermore, peer instruction has been demonstrated to improve student performance, reduce anxiety, enhance attitudes, and improve retention of course material, and it is effective in improving student achievement for members of historically marginalized groups [15], [16]. Overall, combining peer instruction in a classroom environment with mentoring on strategies to connect to undergraduate research opportunities may represent an effective strategy to support students in their learning and in joining a professional community.

Traditional grading strategies represent a primary source of anxiety leading to low self-efficacy for first-year engineering students, since grades signal whether a student belongs in their academic program. Although instructors may attempt to close "the achievement gap" by adopting inclusive teaching strategies, keeping traditional grades especially impacts students with historically marginalized identities in a negative way, suggesting that how student work is evaluated might also contribute to this gap [17]. As a result, traditional grading systems may undermine efforts to create inclusive classroom environments. Several alternative grading strategies have been proposed to support a growth mindset [18]. Specifications grading [19] is a system in which students complete bundles of activities corresponding to their desired grade. Students earn credit for an activity by meeting specifications that are closely aligned with learning objectives. Since specifications are transparently defined for students, specifications grading reduces grade anxiety and enhances student performance. It is an inclusive strategy that empowers students to make choices about their learning [20]. Students are able to focus on professional development and application of knowledge instead of grades, which allows for increased understanding and retention of course material.

This work-in-progress paper describes a novel course, "Starting an Undergraduate Research Experience (SURE): How to Perform Research", which synergistically combines inclusive course design, peer instruction, and specifications grading to reduce barriers to entry into undergraduate research experiences and to increase students' sense of belonging.

Methods

Course Design

The SURE course was offered in the engineering school at our R1 research institution. The course was one credit, graded Credit/No Credit, and met once per week for 50 minutes so it would not significantly add to the already busy course load of first-year engineering students. At our institution all first-year students have a common curriculum and have not yet declared a major. The overall course goal was professional development to lower barriers to getting involved in undergraduate research experiences.

This study included students who took the SURE course during the fall 2024 semester. The total number of students enrolled in the class was 38. Due to the small sample size, we did not collect or analyze demographics information to protect the identities of the students.

The course instructor was a third-year undergraduate engineering student who had previously taken the course and subsequently joined a research lab. As a result, the undergraduate student instructor was uniquely qualified to relate to the student experience in the course. A faculty member mentored the instructor in backward course design principles [21], [22], inclusive pedagogy [23], [24], assessment methods, and student mentoring strategies. They collaborated to design all aspects of the course. The faculty member supported the peer instructor by being present at each class and by meeting at least once a week to reflect and debrief on the previous week's class and to plan future class activities. The undergraduate instructor then led class and office hours sessions, graded student work, and supported students through their course experiences.

The course learning objectives were based on skills needed to successfully join a research lab. The four course learning objectives were (1) to recognize what undergraduate research is, how undergraduate research works, and identify the value of undergraduate research; (2) to gain a deeper understanding of lab environments and identify personal goals for a research experience; (3) to seek out research opportunities and effectively communicate skills and goals; and (4) to be able to find and analyze scientific writing applicable to a topic and become familiar with research deliverables.

Assessment of learning was based on a specifications grading system [19]. To earn Credit for the course, a student needed to meet specifications for each course learning objective. Each objective was supported by multiple assignments, and students needed to complete a designated number of assignments to meet specifications (earn credit) for each objective. Some assignments representing core learning targets were mandatory, and other assignments were optional. This system was flexible and gave students choices, empowering them to complete assignments that best aligned with their individual goals.

A typical learning cycle consisted of interactive class activities followed by weekly journal assignments. The journal assignments provided space for students to demonstrate learning, to reflect on how class activities related to their research interests, and to prepare for the next class or assignment. For example, the journal prompt after a lab tour activity is,

> Please reflect on your lab tour experience. Some questions you might think about when writing are:
>
> - What preconceived notions about a lab environment did you have before the tour? Did those change in any way?
> - What were some of the tasks that the undergrads were performing? Can you envision yourself performing these tasks?
> - How is the lab set up in terms of structure (e.g., are there grad students)? What are the roles of the undergrad?
> - What aspects of the lab did you like/dislike?

To meet specifications for this journal assignment, students were asked to answer at least three of the questions or to include their own individual reflections about their learning during the lab tour.

Each week's class incorporated active learning opportunities. Since the class only met weekly, activities were coordinated through the semester to support spaced retrieval practice, a strategy that supports short- and long-term memory of key concepts [25]. Main content topics are listed below.

- Activities designed to help students learn about the value of, structure of, and roles in undergraduate research
- Undergraduate research student and alumni panels, so students could ask questions to people who have been in their shoes
- Lab tours to visualize themselves inside of a lab role
- Activities designed to help students find research opportunities that they are interested in
- Writing contact emails and resumes
- Mock interviews and learning interview strategies
- Analyzing and discussing research articles through facilitated discussions to model participation in lab meetings

Quantitative Methods

This study was approved by University of Virginia Institutional Review Board (IRB) under protocol number 7133. To assess the effectiveness of the course on student experiences, we used a validated instrument that measures three scales: belongingness, academic engagement, and self-confidence [26]. Students completed the questions (Appendix, Table A1) anonymously before the course began and after the course concluded. Answers were coded as a five-level Likert scale (Strongly Agree, Tend to Agree, Neutral, Tend to Disagree, Strongly Disagree). Some questions were negatively expressed, and answers were adjusted appropriately before computing a student's average score for each scale. Since identifying information was not collected with the survey, pre- and post-course scores could not be compared for individual students. Instead, class average scores for belongingness, engagement, and self-confidence were calculated. Pre- and post-course class average scores were compared using a two-tailed homoscedastic t-test; scores were considered significantly different if $p < 0.05$.

Three additional questions were asked to assess belonging specific to our program: "I feel like I belong in SEAS [School of Engineering and Applied Science]"; "I feel like I belong in my major"; and "I feel like an engineer" [citation blinded]. Responses were coded with a seven-level Likert scale (Strongly disagree, Disagree, Somewhat disagree, Neither agree nor disagree, Somewhat agree, Agree, Strongly agree). As above, pre- and post-course class average scores were compared using a two-tailed, homoscedastic t-test; scores were considered significantly different if $p < 0.05$.

Finally, in the post course anonymous survey we asked students if they had reached out to a research lab or professor (e.g., sent a contact email) and if they had received interest or an offer to join a research lab.

Qualitative Methods

On the last day of class, students completed an anonymous "snowball" reflection activity. On a blank piece of paper, students anonymously wrote their answers to any of the following questions: (1) How have you grown as a researcher throughout this semester? (2) What have you learned about research from this class? (3) What skills or abilities have you gained from this class? Students crumpled their pieces of paper containing their answers into a "snowball" and tossed them into a bin. The snowballs were retrieved after class, and answers were transcribed for thematic analysis to understand what the students took away or learned in the course in their own words.

Using the same three categories as in the quantitative data (self-confidence, belongingness, and academic engagement), we manually coded themes that emerged in the students' responses as listed below.

- Self-confidence
    - Ease of Entry into Undergraduate Research
    - Skill Development
- Belongingness
    - Mentorship and Networking
    - Understanding and Appreciation for Research
- Engagement
    - Professional and Academic Preparation
    - Critical Thinking and Problem-Solving

Both authors coded responses independently and compared results. The authors discussed any differences until they reached agreement on the coding.

Results

Quantitative Analysis

Comparison of the pre- and post-course data revealed general positivity in belongingness, academic engagement, and self-confidence, but values did not increase significantly from the beginning to the end of the course (Fig. 1). The class average belonging score increased from 3.95±0.53 (mean±SD, n = 37) to 4.00±0.50 (mean±SD, n = 38, p = 0.69). The class average engagement score decreased from 4.14±0.52 (mean±SD, n = 37) to 4.07±0.49 (mean±SD, n = 38, p = 0.53). The class average self-confidence score increased from 3.47±0.58 (mean±SD, n = 37) to 3.57±0.62 (mean±SD, n = 38, p = 0.45).

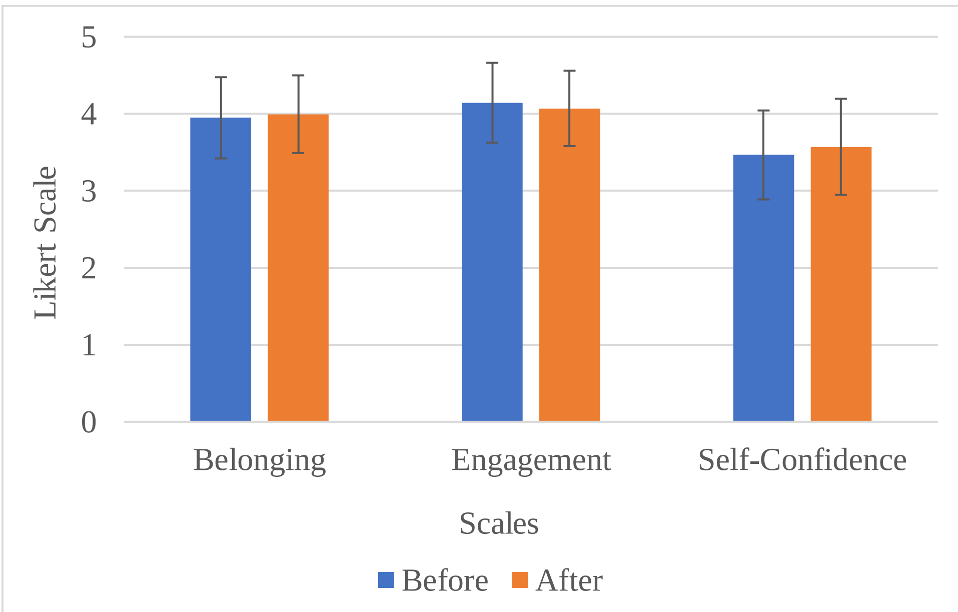

Figure 1. Students' sense of belonging in the university, engagement, and self-confidence before and after the course (five-level Likert scale [26]**).**

Students were similarly positive about their sense of belonging in our program (Fig. 2), and scores did not increase significantly from the beginning of the semester to the end. The class average score for belonging in SEAS increased from 5.75±1.18 (mean±SD, n = 37) to 5.84±1.17 (mean±SD, n = 38, p = 0.74). The average class score for belonging in their major increased from 5.89±0.83 (mean±SD, n = 37) to 6.00±1.04 (mean±SD, n = 38, p = 0.61). The average class score for feeling like an engineer increased from 5.00±1.47 (mean±SD, n = 37) to 5.58±1.03 (mean±SD, n = 38, p = 0.053).

Finally, post-course survey results indicated 20 students had reached out to a professor or a research lab about getting involved. Out of those 20 students, 11 received interest or an offer of a position in a lab.

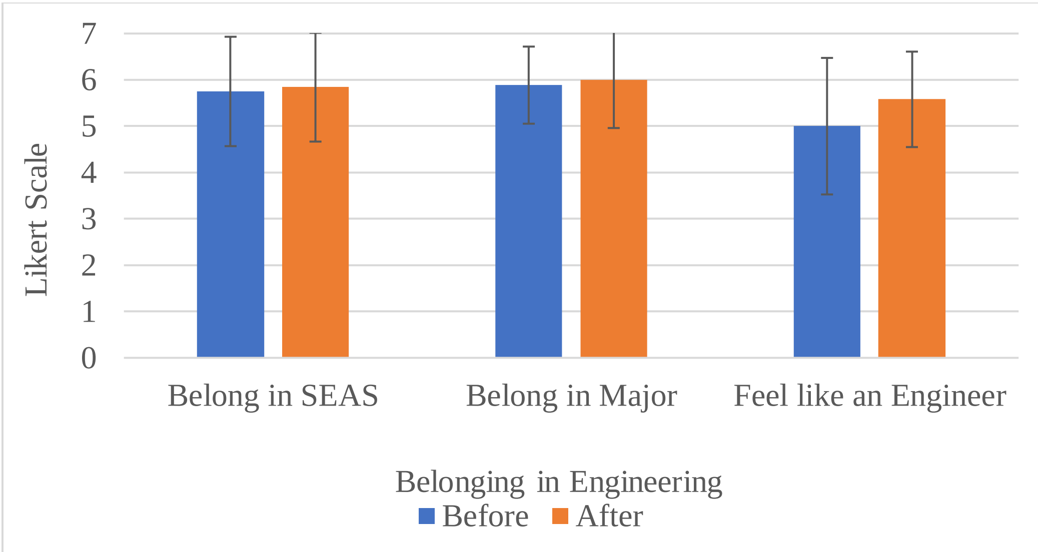

Figure 2. Sense of belonging in SEAS and major and feeling like an engineer before and after the course (seven-level Likert scale).

Qualitative Analysis

Students' reflections on their learning in the end-of-course "snowball" activity were coded based on emergent themes in the categories of self-confidence, belonging, and engagement. The total numbers of student responses in each theme (Table 1) revealed learning especially included skill development and an understanding and appreciation of research. More than half of respondents' answers mentioned these two themes. The numbers of responses in each theme broken down by individual question in the "snowball" activity is reported in the Appendix (Table A2).

Table 1. Total numbers of student responses associated with each theme that emerged from student responses in the "snowball" activity.

Category	**Theme**	**Number of Responses**	**Number of Responses With 2 or More Mentions**
Self-Confidence	Ease of Entry into Undergraduate Research	17	0
	Skill Development	52	20
Belonging	Mentorship and Networking	13	0
	Understanding and Appreciation of Research	29	4

Category	Theme	Number of Responses	Number of Responses With 2 or More Mentions
Engagement	Professional and Academic Preparation	12	0
	Critical Thinking and Problem Solving	5	0

Discussion

In this work-in-progress study we report preliminary observations in a first-year course designed to lower barriers to entry into undergraduate research experiences. More than half of students reached out to professors and/or research labs about research experiences, and more than half of those students received offers to join a lab. In an anonymous end-of-course activity, most students indicated they gained an understanding and appreciation of research and learned skills associated with finding and joining a research lab. These results suggest that most students successfully achieved their learning objectives and felt able to pursue undergraduate research opportunities.

The preliminary data suggests first-year engineering students at our institution feel a relatively high initial level of belonging and self-confidence before participating in the SURE course. One hypothesis is first-year students feel prepared for and enthusiastic about college and engineering coursework, reflecting an initial optimism based on their experiences in math and science courses in high school [27]. Students' perceptions of belongingness in the university, self-confidence, sense of belonging in SEAS and in major, and feeling like an engineer increased from the beginning to the end of the SURE course, although the changes in Likert scores were not statistically significant. In the future, it would be interesting to explore whether sense of belonging in a particular academic department is related to sense of belonging in the university. The increase in feeling like an engineer is consistent with acquisition of engineering identity in first-year students, which usually occurs due to experiences at their home institutions [28]. In the case of the SURE course, peer instruction may represent one factor that supports increased engineering identity [29].

An alternative interpretation of the data is that student perceptions are unique to our institution. The proportion of students in our engineering school who identify with historically marginalized groups is underrepresented with respect to the demographics of our state, and we have not compared other factors such as first-generation or socioeconomic status to other engineering schools. We would need a larger sample size to collect demographic data for students in the SURE class, allowing comparisons to other schools and programs.

A potential pitfall when interpreting the results involves the specificity of the instruments used to measure student perceptions. The measures of belongingness, self-confidence, and academic engagement developed by Yorke [26] focus on student perceptions within an academic program.

We implemented the instrument, as well as our questions about belonging in school and major and feeling like an engineer, with this idea in mind [7]. It is difficult to directly compare the scores between these two instruments because one uses a 5-level Likert scale and the other uses a 7-level Likert scale. We chose to keep the original scales for comparison to other studies using these instruments. Since we used Yorke's survey instructions, we cannot conclude that the SURE course was the specific cause of change in students' responses. Moreover, collecting data anonymously prevented tracking changes in pairwise fashion. Comparisons between class average scores are less powerful than pairwise comparisons of students' responses before and after completing the SURE course. Designing a data collection and analysis strategy to enable more specific inquiry into the effect of the SURE course will be explored in the future.

To evaluate the specificity of the SURE course in lowering barriers of entry into undergraduate research and increasing students' sense of belonging and self-efficacy, we will compare SURE students' responses to those of a student cohort that did not experience the SURE course. The comparison cohort will include similar student demographics and stages of academic progress (mostly first-year students). This analysis will include interest in research as an additional factor to further understand if the positive results from SURE class are dependent on the class itself or students' attitudes towards research. Such an approach will account for other influences of first-year experiences, clubs, and courses that contribute to increased belonging and self-confidence.

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Appendix

Table A1. Survey instrument to measure students' sense of belonging in the university, academic engagement, and self-confidence in their academic major. Responses were a five-level Likert scale (Strongly Agree, Tend to Agree, Neutral, Tend to Disagree, Strongly Disagree). Adapted from [26].

Question Number	Question Asked to What Extent	Scale
1	I am motivated towards my studies.	Engagement
2	I feel at home in this university.	Belonging
3	I expect to do well in my major.	Self-Confidence
4	Being at this university is an enriching experience.	Belonging
5	I try to make connections between what I learn from different courses.	Engagement
6	I try to do more than what my courses require of me.	Engagement
7	I wish I'd gone to a different university.	Belonging (Reverse Scored)
8	I seek out academic staff in order to discuss topics relevant to my major.	Engagement
9	I worry about the difficulty of my major.	Self-Confidence (Reverse Scored)
10	I put a lot of effort into the work I do.	Engagement
11	I have found research to be welcoming.	Belonging
12	I use feedback on my work to help me improve what I do.	Engagement

Question Number	Question Asked to What Extent	Scale
13	I doubt my ability to study at university level.	Self-Confidence (Reverse Scored)
14	I am shown respect by members of staff in this department.	Belonging
15	Sometimes I feel I don’t belong in this university.	Belonging
16	I’m confident of completing my major successfully.	Self-Confidence (Reverse Scored)

Table A2. Mapping of end-of-course “snowball” activity responses to emergent themes related to self-confidence, belonging, and academic engagement. Questions were as follows: (1) How have you grown as a researcher throughout this semester? (2) What have you learned about research from this class? (3) What skills or abilities have you gained from this class? Total numbers of responses; numbers of responses with two or more mentions in a theme are shown in parentheses.

Category	Theme	Q1 Total (Multiple mentions)	Q2 Total (Multiple mentions)	Q3 Total (Multiple mentions)
Self-Confidence	Ease of Entry into Undergraduate Research	7	9	1
	Skill Development	17 (5)	4	31 (15)
Belonging	Mentorship and Networking	4	5	4
	Understanding and Appreciation of Research	7	20 (4)	2

Category	**Theme**	**Q1 Total (Multiple mentions)**	**Q2 Total (Multiple mentions)**	**Q3 Total (Multiple mentions)**
Engagement	Professional and Academic Preparation	3	6	3
	Critical Thinking and Problem Solving	3	1	1