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”People-Oriented Recitation Problems”: Assessing the Impact of a Contextualized Recitation Intervention on First-Year Student Interest in Chemical Engineering

Gabriel Azure Antonio Mendez-Sanders, Carnegie Mellon University

Gabriel Mendez-Sanders is a fifth year student and researcher in Carnegie Mellon University’s Department of Chemical Engineering.

Heather Phillips, University of Pittsburgh

Heather Phillips is a BPhil graduate in Engineering Physics from the University of Pittsburgh and an incoming Electrical Engineering PhD student at Stanford University.

Dr. Joanne Kay Beckwith, Carnegie Mellon University

Joanne K. Beckwith Maddock is an Assistant Teaching Professor of Chemical Engineering at Carnegie Mellon University.

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Introduction

Engineering programs in the U.S. face persistent retention challenges, with 40-60% of all engineering students changing majors or leaving college before completing their degrees [1]. In Chemical Engineering (ChemE), enrollment has been declining since 2020 and is expected to continue dropping in the coming years [2]. Engineering attrition is particularly high in the first year [3, 4], largely due to the abstract and difficult content of introductory courses, which contribute to academic stress and waning interest [5, 6].

To address engineering retention challenges, universities have implemented various supportive strategies including promoting mental health resources [7], fostering inclusive learning environments [8], and nurturing students’ development of engineering identities [9]. Additionally, efforts to build student interest and clarify career outcomes have led to increased use of contextualization—linking theoretical content to real-world applications to enhance engagement and highlight career pathways [10]. This study builds on these efforts by uniquely contextualizing recitation problems with faculty research, providing first-year students with a direct link to ongoing work within their department.

This study evaluated the effectiveness of “People-Oriented Recitation Problems” (PORPs), a novel intervention the researchers designed to improve first-year students' engagement and retention in ChemE. PORPs integrate faculty research into recitation problems, demonstrating real-world applications of academic concepts. Guided by Social Cognitive Career Theory (SCCT), this research examined PORPs’ impact on students' career interests, choice goals, and outcome expectations in ChemE. Using a mixed-methods approach—incorporating surveys, enrollment data, and focus groups—this study will inform ChemE educators about the potential for people-oriented, context-rich recitation problems to inspire interest and improve retention in engineering.

Background

The PORP intervention introduced and evaluated in this study builds on prior work in first-year engineering education and contextualization to enhance student engagement in ChemE. First-year engineering students often struggle with motivation and retention due to the abstract and rigorous nature of technical coursework, which can lack clear practical relevance [11] - [16]. By embedding technical concepts within real-world contexts and linking course content to professional applications through contextualization, educators have found ways to increase student engagement and connection to the field [17] - [22].

I. First-Year Engineering Education

The PORP intervention was designed to complement the strengths and address the weaknesses of the traditional approach to first-year engineering education. Most U.S. programs follow a core curriculum of mathematics, physics, chemistry, and introductory engineering concepts [11], but their structure varies—some introduce broad engineering principles before major declaration, while others incorporate major-specific coursework from the start [12]. At the study institution, engineering students declare their major in March of their second semester, while taking their second selected introductory engineering course. While foundational technical courses are critical for building a strong academic base, these introductory engineering courses can also be significant sources of stress, contributing to high attrition rates across engineering disciplines [4, 13, 14]. The introductory courses often emphasize theoretical knowledge, which can feel intangible and disconnected from real-world applications, leaving students questioning how their learning aligns with future engineering careers [15]. This disconnect is particularly pronounced in ChemE, which historically has struggled to incorporate practical applications into theoretical course content [16]. As a result, first-year students may struggle to see ChemE's relevance, dampening their interest and engagement with the discipline. In an effort to connect course content to practical applications, the PORP intervention modifies recitations with a novel form of contextualization to build foundational skills and indicate real-world relevance.

II. Contextualization

PORPs aim to improve first-year student engagement by using faculty research slides to contextualize recitation problems. Contextualization in engineering education links technical content to real-world applications, helping students grasp abstract concepts while emphasizing engineering's societal impact [17], [18]. This approach fosters technical competence and informed decision-making in global, economic, environmental, and social contexts [18], [19]. Engineering curricula often achieve this through case studies, industry examples, and interdisciplinary projects, which highlight the connection between technical knowledge and real-world challenges [20].

While real-world problems are most often used to contextualize content in capstone or later design courses [17], [20], early contextualization has the potential to boost motivation, performance, and persistence in engineering [21], [22]. Early contextualization would be especially valuable in fields like ChemE, where the relevance of technical concepts may not be immediately clear to newcomers [16]. To address this need for early contextualization for ChemE students, this study analyzed the effects of contextualizing first-year recitation problems with relevant faculty research and real-world impact.

Theoretical Foundation: Social Cognitive Career Theory

Social Cognitive Career Theory (SCCT) [23], [24] is a well-suited framework for evaluating the effects of PORPs because it focuses on the relationship between self-efficacy, outcome expectations, and career interests—key factors in engaging first-year ChemE students. SCCT uniquely highlights how students' beliefs in their ability to succeed and their perceptions of the rewards associated with academic tasks (e.g., PORPs) shape their career interests and decisions. SCCT governed this study's survey items, focus group questions, data analysis, and recommendations for using PORPs in engineering classes. SCCT is composed of three interconnected models that focus on different aspects of career development: the Choice Model, the Performance Model, and the Interest Model. The Choice Model explains how individuals select educational or career paths based on their self-efficacy and outcome expectations, while the Performance Model examines how these factors influence their persistence and achievement in those paths. This study will focus on the Interest Model, as it is particularly relevant for understanding how students' interest in ChemE evolves through the use of PORPs.

I. The Interest Model in Detail

According to SCCT's Interest Model, self-efficacy and outcome expectations are key drivers of interest development:

- **Self-Efficacy** is an individual's belief in their ability to succeed in specific tasks. For first-year ChemE students, confidence in their ability to solve engineering problems and understand complex technical concepts can influence their interest in the field. When students feel capable and supported through relevant problem-solving activities (i.e., PORPs), their self-efficacy in engineering tasks can increase, boosting their interest in the discipline.
- **Outcome Expectations** are an individual's beliefs about the potential outcomes of performing specific short- and long-term activities. PORPs aim to show students how success in short-term course tasks (e.g., recitation problems, exams) can lead to achieving short-term desirable outcomes (e.g., undergraduate research opportunities in areas of interest). This short-term success can foster persistence in long-term tasks (e.g., declaring ChemE and graduating) to fulfill long-term desirable outcomes (e.g., attaining jobs and success in areas of interest).

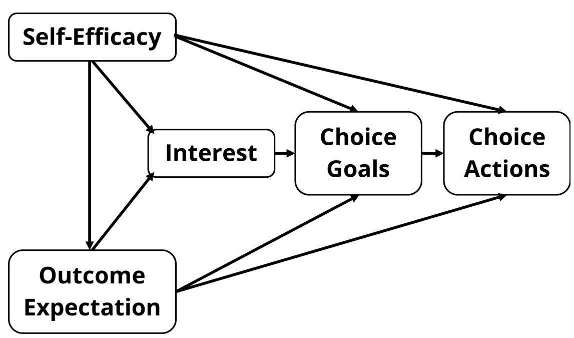


Figure 1. Social Cognitive Career Theory posits self-efficacy and outcome expectation as having a combined impact on career interest and career choice [24].

Both self-efficacy and outcome expectations drive interest in ChemE, which shapes students' career goals (choice goals) and the steps they take to achieve those goals (choice actions), as illustrated in Figure 1. The researchers anticipate that as students build confidence in their abilities and recognize the real-world relevance of the material, their interest in the field will deepen. This growing interest drives their choice goals—intentions to pursue ChemE as a career—and translates into choice actions, such as declaring ChemE as their major and seeking related internships or research opportunities.

SCCT provides a useful lens for understanding how self-efficacy and outcome expectations interact to shape students' interest in engineering. By embedding real-world contexts and relevant faculty research in recitation problems, PORPs aim to enhance these two factors, making students feel more capable and more aware of the rewards of pursuing ChemE, ultimately increasing their engagement and likelihood of pursuing the field further.

Methods

I. Study Setting, Course Background and Intervention Explanation

The PORP intervention was introduced in an Introduction to Chemical Engineering (Intro ChemE) course at a small, private, R1 institution in the northeastern U.S. At this institution, engineering students declare their major in March of their second semester, while taking their second selected introductory engineering course. Intro ChemE, offered each Fall (≈50 students) and Spring (≈25 students), primarily enrolls undeclared first-years, reflecting the institution's broader demographics, with Hispanic/Latino and BIPOC groups underrepresented. The key learning outcomes for the course are to develop skills in data analysis, material balances, and determining state properties.

Intro ChemE meets for five hours weekly: three hours of lectures, one hour of lab, and one hour of recitation. Recitation sessions involve small groups working on structured exercises or case studies—known as recitation problems [25], [26]—based on the material covered in the previous lectures. Students collaborate in consistent five-person teams for all recitations, homework, and lab experiments, with teams switching mid-semester. Attendance for recitation is mandatory, and students submit their work for participation credit.

For the 2024-2025 academic year, both traditional recitation problems and PORPs were used to compare their effects on student learning and interest. Unlike traditional recitation problems, PORPs uniquely contextualize recitation content with specific faculty members, their research areas, and the broader societal impacts of that research. Each PORP begins with a faculty slide illustrating the connection between their research and the recitation topic, bridging classroom learning with real-world applications (see Appendix I for an example of a PORP faculty slide). After viewing the slide, the students watch a video in which the faculty member introduces themselves, fostering a more personal connection to the faculty and their work. By strengthening first-year students' connections to faculty research, PORPs aim to encourage interest in ChemE and prompt consideration of undergraduate research opportunities and career pathways.

II. Researcher Positionality

This section outlines the researchers' backgrounds to acknowledge how their perspectives shaped the study's design, interpretation, and conclusions.

The first author identifies as a Latino, White, pansexual, cisgender male. Having recently completed a Bachelor's degree in ChemE at the study institution, he is well-acquainted with the department and Intro ChemE. This familiarity facilitated rapport with participants and offered valuable insights into the course experience, but also introduced potential bias, as his experiences and aspirations for the course may influence the study's findings.

The second author identifies as a white, cisgender female. She is a senior undergraduate student in Engineering Physics at a different institution. She has experience with engineering education within an Electrical Engineering context. This external perspective brings critical insights that complement the first author's familiarity with the study setting.

The third author identifies as a white, cisgender female. She has a bachelor's, master's, and doctoral degree in ChemE and spent several years working in industry between her undergraduate and graduate studies. As an Assistant Teaching Professor in the ChemE department and the course instructor for Intro ChemE, she developed the intervention under investigation, bringing an in-depth understanding of its objectives and implementation.

III. Research Questions

This study evaluated the effectiveness of "People-Oriented Recitation Problems" (PORPs), a novel intervention the researchers designed to enhance engagement in a first-year undergraduate introductory ChemE course. To evaluate the impact of PORPs, this study included two primary research questions:

1. To what extent do PORPs influence first-year students' interest in chemical engineering and its subfields?
2. To what extent do PORPs affect first-year students' intention to pursue chemical engineering?

To answer these questions, a mixed-methods approach was employed, incorporating data from surveys, focus groups, and enrollment trends.

IV. Data Collection

The study collected data over the Fall 2024 and Spring 2025 semesters. Using an ABAB design, half of the course topics in each semester incorporated PORPs, while the other half used traditional recitation problems, as shown in Table 1. The topics that included PORPs in the Fall Semester did not use them in the Spring Semester, and vice versa. This design allowed for comparison between topics within a semester, and across semesters for the same topic. This paper reports on the Fall 2024 data sample.

Table 1. ABAB experimental study design. Black boxes are topics which used PORPs, the white boxes are topics which used traditional recitation problems.

Fall 2024	**Spring 2025**
Biotechnology & Pharmaceutical Engineering	Biotechnology & Pharmaceutical Engineering
Process Systems Engineering	Process Systems Engineering
Energy, Decarbonization, & Sustainability	Energy, Decarbonization, & Sustainability
Air Quality & Climate	Air Quality & Climate
Soft Materials & Complex Fluids	Soft Materials & Complex Fluids

Surveys were conducted twice per semester: during the second week (before the first recitation) and the final week of classes (after the last recitation). Additionally, an in-person focus group was held during the final exam week each semester. Students could earn extra credit for participating in the start-of-semester survey, end-of-semester survey, and focus group (i.e., up to three extra credit opportunities). Alternative extra credit assignments of equivalent time commitment were offered for each of the three study components. *Note: Extra credit incentive was not IRB-approved until 11/13/2024, so no extra credit was awarded for the Fall 2024 start-of-semester survey.*

V. Surveys

This study investigated the impact of PORPs on first-year students' interest and choice goals in ChemE, guided by SCCT. Previous STEM education research has measured student interest using SCCT-based instruments like the STEM Career Interest Survey (STEM-CIS), which was originally designed for K-12 students and validated for engineering (RMSEA = 0.017, CFI = 0.990, NFI = 0.950) [27]. This study adapted the STEM-CIS engineering subscale for undergraduate ChemE students by modifying six items and introducing two new items to assess understanding of ChemE and self-efficacy for post-graduation ChemE careers. These items were measured on a Likert-scale, from 1 (strongly disagree) to 5 (strongly agree). Additionally, interest in ChemE subfields corresponding to the five course topics was rated on a scale of 1 (not at all interested) to 5 (extremely interested). Appendix II lists all 13 quantitative survey items used in the start-of- and end-of-semester assessments.

Quantitative data were analyzed using descriptive statistics (e.g., mean, standard deviation, frequency distribution) and inferential statistics (e.g., t-test, two-proportion z-test, one-factor ANOVA with Bonferroni post hoc tests) to track changes in self-efficacy, outcome expectations, and interest in ChemE and its subfields.

The survey also included three open-ended prompts:

- Please list all skills that you will develop/have developed in Carnegie Mellon University's 06-100 Intro to Chemical Engineering class.
- Please list all career paths that chemical engineering students can go into.
- Please list any other chemical engineering fields you may be interested in.

The open-ended responses underwent qualitative-to-quantitative coding, categorizing them into predefined or inductive codes and themes, allowing for statistical analysis of patterns or trends in the data. This analysis provided insights into students' evolving perspectives on ChemE and any emerging interests or misconceptions about the field (see section VI. Focus Groups for more on thematic analysis). To mitigate survey item misinterpretation, data triangulation cross-referenced survey trends with more contextually-rich focus group discussions.

VI. Focus Groups

At the end of each semester, a focus group was conducted to provide qualitative context for survey trends. Focus groups were selected for qualitative data due to time efficiency and their ability to foster candid responses in a comfortable, peer-based setting. Each session included up to 10 students who self-registered on a first-come-first-serve basis after in-person and virtual recruitment. The focus groups lasted approximately 75 minutes, beginning with broad questions on Intro ChemE, progressing to reflections on course learning activities, and ending with targeted questions about PORPs (see Appendix III for the full list of focus group questions).

Focus group discussions were transcribed using Otter.AI, validated by the authors, and then analyzed via thematic analysis. Initial codes and themes were generated inductively, then revised to ensure alignment with SCCT and the research questions, forming a preliminary codebook. Transcripts were then re-coded independently to assess consistency, with inter-rater reliability calculated using Cohen's Kappa. Once coding was finalized, the refined themes were presented to the focus group participants for feedback. Member checking ensured themes accurately reflected participants' perceptions of PORPs and their impact on students' interest and engagement in ChemE.

Finally, focus group themes were triangulated with open-ended survey responses. All qualitative data was thoroughly examined for negative evidence regarding the efficacy of PORPs to mitigate observer bias, ensuring that the recommendations reflect the multifaceted impacts of PORPs on students' interest and persistence in ChemE.

Results

I. Quantitative Survey Data

In fall, the start-of-semester survey response rate was 28.8% (N = 15), while the end-of-semester response rate increased to 92.3% (N = 48), likely due to the added extra credit incentive. End-of-semester survey items showed approximately normally distributed histograms; start-of-semester distributions were less normal in shape, likely due to the smaller sample size.

Among ChemE subfields, Air Quality & Climate (AQC) and Process Systems Engineering (PSE) had the highest end-of-semester interest, with respective means of 2.88 (SD = 1.10) and 3.00 (SD = 1.11) on a 5-point scale. T-tests were used to compare changes in mean item scores across semesters. PSE was the only subfield to have a significant change in mean interest ($p < 0.05$), increasing by 0.533 from the start-of- to end-of-semester observations (Figure 2).

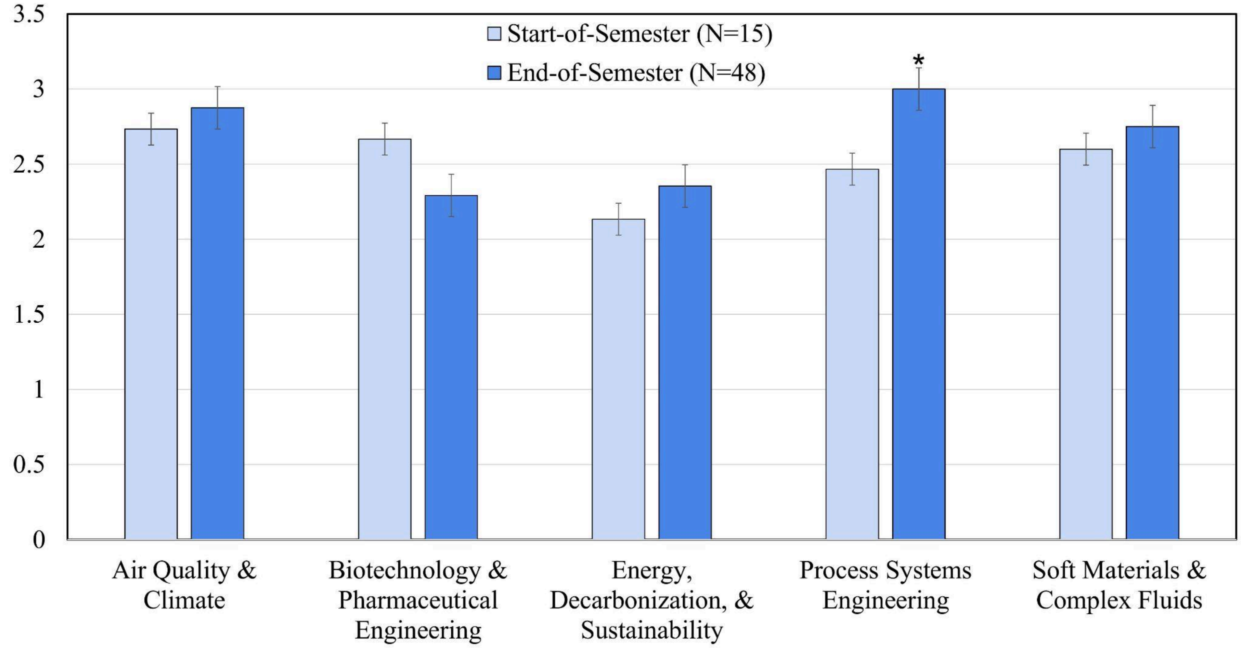


Figure 2. Average start-of- and end-of-semester interest in ChemE subfields. Interest was measured on a Likert-scale (1 = not at all interested, 2 = slightly interested, 3 = somewhat interested, 4 = very interested, 5 = extremely interested). Error bars represent a 95% confidence interval. PSE was the only subfield with a statistically significant interest change, indicated by *.

A one-factor ANOVA with Bonferroni post hoc tests revealed a significant difference in end-of-semester subfield interest, $F(4, 235) = 3.89$, $p < 0.01$. PSE had significantly more end-of-semester interest than Biotechnology & Pharmaceutical Engineering (B&PE) ($p < 0.01$) and Energy, Decarbonization, & Sustainability ($p < 0.01$). Additionally, AQC had significantly more end-of-semester interest than B&PE ($p < 0.01$).

For SCCT measures, the only significant change across the semester was an increase in students' belief that their ChemE courses would prepare them for post-graduation success ($p < 0.05$), reflecting an increase in positive outcome expectation. Other measures of self-efficacy, outcome expectation, choice goals, and interest increased but were not statistically significant ($p > 0.05$).

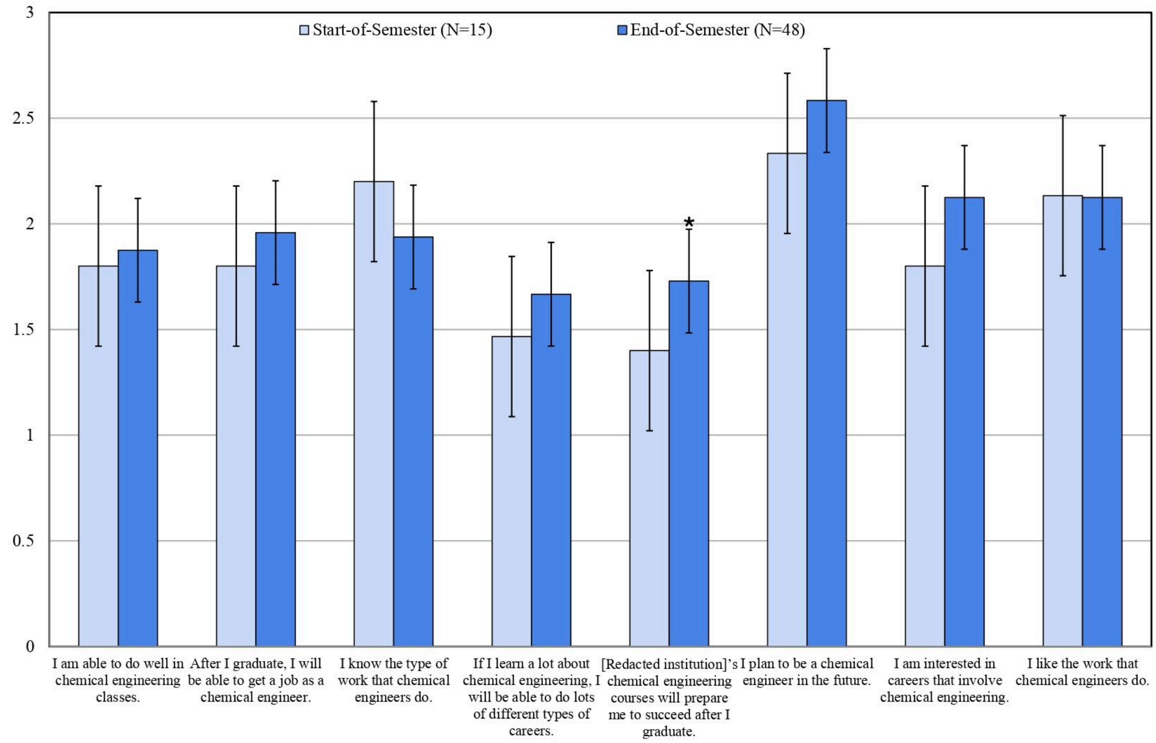


Figure 3. Average start-of- and end-of-semester agreement for SCCT items. Agreement for each item was measured on a Likert-scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). Error bars represent a 95% confidence interval. While most SCCT items showed an increase in average score, expected post-graduation ChemE success (outcome expectation) was the only statistically significant change, indicated by *.

II. Qualitative Survey Results

The average number of career paths listed per response decreased from 5.47 to 4.58 over the semester, though not significantly (Table 2). Career paths were coded based on the course's five topics, tracking changes in the number and proportion of responses linked to topics that incorporated PORPs versus those that did not. Over the semester, the average number of ChemE course topics coded per respondent increased slightly from 2.87 to 2.96, but not statistically significantly. No significant changes were observed in the proportions of career paths coded to each course topic.

Table 2. Changes in number of career paths listed, ChemE topics coded, and proportion of responses coded for each course topic. Since responses could be coded for multiple topics, proportions reflect the fraction of total responses coded for each topic, not the fraction of codes, and thus do not sum to 1. None of the displayed changes were statistically significant.

"Please list all career paths that chemical engineering students can go into."			
	Start-of-Semester (N=15)	End-of-Semester (N=48)	T-test *p*-value
Average number of career paths listed per respondent	5.47	4.58	0.08
Average number of coded ChemE topics per respondent	2.87	2.96	0.40
Responses coded for career path topics	Start-of-Semester (N=15)	End-of-Semester (N=48)	T-test *p*-value
Proportion coded 'Air Quality & Climate'	0.333	0.125	0.18
Proportion coded 'Biotechnology & Pharmaceutical Engineering'	0.667	0.771	0.75
Proportion coded 'Energy, Decarbonization, & Sustainability'	0.533	0.625	0.60
Proportion coded 'Process Systems Engineering'	0.533	0.583	0.57
Proportion coded 'Soft Materials & Complex Fluids'	0.133	0.125	0.13

A greater proportion of end-of-semester respondents (25.0%, N = 12) listed additional ChemE subfields of interest compared to start-of-semester respondents (13.3%, N = 2), though a two-proportion z-test found this difference not statistically significant. Notably, end-of-semester responses included more non-traditional ChemE fields, such as "consulting," "finance," and "genetics."

III. Focus Group Results

Ten students participated in the fall focus group; each selected their own pseudonym. Three predominant themes emerged for the PORPs intervention:

1.) Broadening Knowledge for Future
2.) Student Learning and Engagement
3.) Trade-offs in Recitation Time Allocation

These themes emerged from 11 final codes (see Tables 3, 4 and 5). The most prevalent theme, Broadening Knowledge for the Future, accounted for 48.3% of all applied codes, while the most applied code was Introduction to Field (Figure 4). Overall, 85% of applied codes were wholly positive in sentiment.

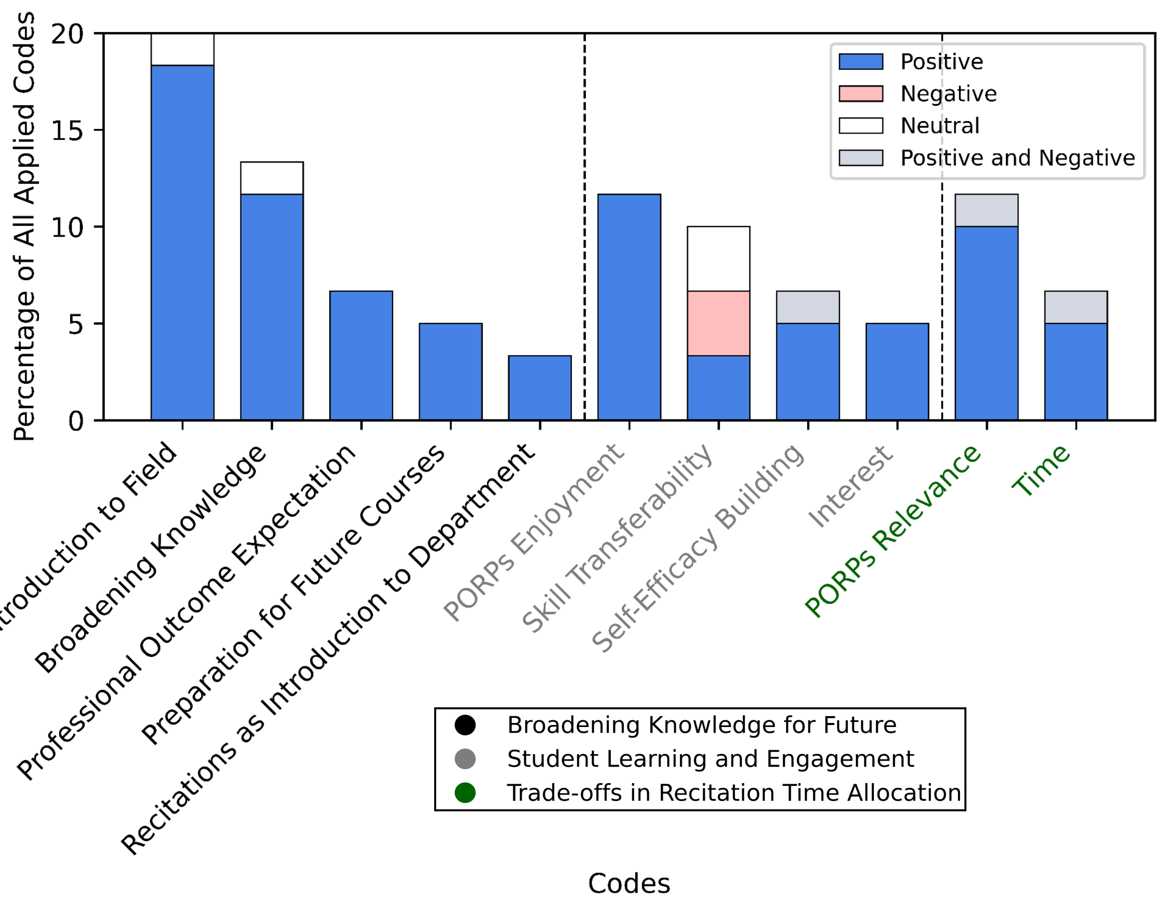


Figure 4. Relative frequency of each code in the fall focus group. Bar colors indicate code types, while label colors indicate which theme the codes belong to. Codes may overlap as multiple can apply to the same text. The most prominent theme was Broadening Knowledge for Future, and the most applied code was Introduction to Field.

Theme 1: Broadening Knowledge for Future

Participants highlighted how PORPs expanded their understanding of ChemE, aiding in decisions about their major and careers while fostering connections with the ChemE department.

Table 3. Broadening Knowledge for Future codes and definitions.

Code	Definition
Introduction to Field	The role of recitations, or the course more broadly, in providing an overview of the field of ChemE (industry and/or research) to help students decide whether to pursue the major or not.
Broadening Knowledge	How learning about faculty research, or the course in general, broadens student awareness of the ChemE research areas, exposing them to new areas and fields within ChemE.
Preparation for Future Courses	How recitations, or the course in general, equip students with foundational knowledge needed for subsequent chemical engineering courses.
Professional Outcome Expectation	How PORPs or the course affected students' personal outcome expectations for pursuing ChemE or their desired outcomes. Includes instances where students connect PORPs or the course to discovering their path or seeing what jobs or research they might want to pursue.
Recitations as Introduction to Department	The role of recitations and/or PORPs in providing introduction to the Department of ChemE and/or the people within it.

Eight participants noted that recitations introduced them to the field, while six credited PORPs with broadening their awareness of research and career opportunities in ChemE. One participant emphasized the value of this exposure:

> **Anna:** "I really liked the faculty slides and videos beforehand. It gave context to the problem and… examples of what we could do. I didn't know there were that many aspects of chemical engineering, and it was interesting to see, oh, you do this with a chemical engineering degree, you could do this with a chemical engineering degree."

Beyond research exploration, students found the course prepared them for future ChemE coursework and provided insight into professional outcomes:

> **Dustin:** "...it does its job as getting someone who's brand new into engineering to just understand the direction of what chemical engineering is, and the type of thinking and knowledge they need to acquire throughout their time here."

PORPs also helped students connect with the ChemE department and its faculty:

> **Mary:** "… I feel like I got to know the department beyond just the intro course. Because, obviously, as an intro course a lot of people in the class aren't even taking chemical engineering. I thought it was good to be introduced to the different concentrations within ChemE."

Mary's comment reflects the sentiment of a group of participants who saw it as important that the course and recitations provide students with an introduction to the field and broaden their knowledge for future work and studies in ChemE.

Theme 2: Student Learning and Engagement

Participants found PORPs engaging, enjoyable, and valuable for skill development. The technical recitation components were linked to building self-efficacy and skill transferability, though these responses reflected a mix of positive and critical feedback.

Table 4. Student Learning and Engagement codes and definitions.

Code	Definition
PORPs Enjoyment	Discussion of enjoyment of PORPs and its components.
Interest	How PORPs or recitations influence students' curiosity, interest, and motivation in the field, or instances in which students express "interest" in PORPs or recitations.
Self-Efficacy Building	Recitation activities that build students' confidence in their ChemE abilities and indicate to themselves their competence.
Skill Transferability	Opportunities to apply theoretical knowledge or skills in recitations or transferring skills from recitations. Students' recognition of how problem-solving and technical skills developed in the recitations can apply or fail to apply in other parts of the course or professional contexts.

Most discussions about PORPs were positive, with five participants expressing enjoyment and three expressing interest in the people-oriented introductions:

> **Justin:** "I liked the segment [PORP] we did for polymers… I think, at least me personally, that was a pretty interesting part of ChemE research. So I liked seeing that."

> **Sophia:** "I think it's also really cool hearing about what research they're doing right now."

These comments highlight participants' interest in the research areas explored in PORPs and excitement about the opportunity to engage with current, relevant work. With regards to the technical recitation components, three students expressed feelings of confidence in their abilities and/or effective skill transfer:

> **Sophia:** "I mean, some of the recitation problems… made me think 'Oh, I know what's going on. I saw this in lecture, and I can actually do it by myself or with the group.'"

However, Sophia and another student also felt recitation problem-solving did not always transfer to other contexts and that a sufficient number of technical examples were not provided:

> **Sophia:** "I knew that I could solve the recitation problems. I knew all the steps, and then sometimes I'd get to the homework, and it'd be like nothing I'd seen, and a lot of times I'd go back to try to find a recitation problem about it, and there just wouldn't be one."

This desire for more technical examples connects to theme 3, reflecting the trade-offs between allocating recitation time to contextualize problems versus covering more technical content.

Theme 3: Trade-offs in Recitation Time Allocation

Participants held somewhat mixed views on whether allocating recitation time to PORP introductions was worthwhile. Most found the content relevant and supported dedicating time to the intervention, though perspectives varied based on differing expectations of recitations and Intro ChemE's goals.

Table 5. Trade-offs in Recitation Time Allocation codes and definitions.

Code	Definition
Time	References to time in recitations, including comments on how recitation time is spent or the amount of time spent on a recitation topic or area.
PORPs Relevance	Discussion of whether PORPs were useful and relevant to the students, to the topic, and/or to the course.

Though only three participants mentioned recitation time in relation to PORPs, their responses were passionate. Mary shared two responses that highlighted her positive view of the time spent on PORPs:

> **Mary:** "I think it was important that we took that time instead of solving problems which can be done on your own, in your own time."

> **Mary:** "I also thought that you could find that on your own, but it was good that we were introduced to that, that class time was taken to introduce that, because I probably wouldn't have gone out on my own and found that type of information. I thought it was really helpful to me."

Mary's comments indicate that she found PORPs highly relevant and worthwhile. On the other hand, Hailey acknowledged their relevance but questioned the balance in time between introductions and problem-solving:

> **Hailey:** “I think we spent a really long time introducing the professor. The video was great. I don't know that we needed the video and the slides, both to introduce it so then we could only do one problem from that, maybe two.”

While this comment expresses reservations about time allocation, no participant indicated that PORPs were irrelevant or unnecessary. Many students voiced a desire for more challenging problems during class, but these suggestions were generally directed at lecture or the course as a whole, rather than specifically recitations.

Discussion

I. Summary of Major Findings

Survey data demonstrated that Air Quality & Climate (AQC) and Process Systems Engineering (PSE)—the ChemE subfields that incorporated PORPs—had the highest end-of-semester student interest. PSE also saw the greatest increase in interest, despite starting as one of the least popular subfields. In contrast, Biotechnology & Pharmaceutical Engineering (B&PE) and Energy, Decarbonization, & Sustainability (which used traditional recitation problems) both had significantly lower end-of-semester interest than PSE, and B&PE also had significantly lower interest than AQC. These findings suggest that PORPs effectively increased student interest in related subfields.

While the ChemE subfields with PORPs had the highest end-of-semester interest, there was no significant change in the proportion of students listing these subfields as possible ChemE careers through open-response. This suggests a possible distinction between fields students find most interesting and those most salient to them—those which they are most readily able to list. As a field, ChemE has been working to broaden understanding of the scope of work that is considered by its students [16]. This initiative may have been successful, given that a larger proportion of respondents listed B&PE careers than more traditional ChemE careers, like PSE. Past initiatives may have been effective at making students more aware of other ChemE subfields, but not necessarily increasing interest in them.

General interest and intention to pursue ChemE increased across most SCCT items, but many changes were not statistically significant. A notable exception was a significant increase in outcome expectation for career success due to the institution’s ChemE courses, possibly driven by PORPs exposing students to a large number of department faculty and research opportunities. Despite this, average Likert scores for all SCCT items remained below 3 at both observation points, indicating low overall confidence and interest in ChemE across the cohort. While this study lacks comparative data from previous course iterations, these low averages highlight the need for further research to better understand career interest and confidence within the student body.

The fall focus group reinforced PORPs’ primary impact: broadening students' knowledge of ChemE research and career paths, preparing them for future coursework and career decisions. This prominent theme aligns with the quantitative increase in career confidence. Moreover, seven of ten participants viewed ChemE as highly versatile, offering pathways to succeed in a wide range of industries. This perception was further supported by the breadth of careers listed in the open-ended survey responses. Students' exposure to diverse faculty research through PORPs likely shaped this sense of versatility. This exposure not only deepened their understanding of ChemE but also fostered a stronger connection to the department, aiding their decisions to declare the major. Participants appreciated that the research showcased was both current and actively conducted within their institution.

Overall, students expressed enthusiasm for PORPs, mirroring the high quantitative interest in the subfields which used PORPs. While PORPs were effective in introducing students to research areas of interest, some noted difficulty transferring technical skills from recitations to other coursework. Two participants desired more technical examples in recitations, and one suggested shortening the PORP intervention to allocate more time for technical content. Still, three participants explicitly valued the time spent on PORPs, emphasizing the relevance of faculty slides and videos. These mixed perspectives highlight the trade-offs in integrating contextualized interventions like PORPs in a time-constrained curriculum. Future iterations should carefully balance the benefits of using faculty research to contextualize recitation problems against the need for more technical content to maximize the intervention's overall effectiveness.

II. Study Limitations

This study was conducted at a single small, private, R1 institution over one academic year, limiting its generalizability. Small sample sizes (N = 15 and N = 48) constrained statistical power, and voluntary participation introduced potential self-selection bias, particularly for the fall start-of-semester survey (28.8% participation rate). The lack of an incentive for the Fall start-of-semester survey likely contributed to the low response rate and potential nonresponse bias, reducing representativeness and the ability to detect significant changes in items. To address participation challenges, the spring semester introduced separate extra credit incentives for each survey.

Parametric analyses were applied consistently, but violations of normality in some start-of-semester items posed limitations. While parametric methods are generally robust to moderate normality violations, their reliability diminishes with smaller sample sizes, potentially affecting early-semester results.

The study employed an ABAB design to compare PORPs to traditional recitation problems within and across semesters, but lacked a fully controlled experimental setup. Differences between the fall and spring cohorts, such as initial interest or commitment to ChemE, may have influenced the observed effects of the intervention.

The study also adapted a previously validated survey instrument but did not conduct confirmatory factor analysis, which could have strengthened confidence in the adapted survey measure. Reliance on self-reported data introduced possible response bias, and survey anonymity prevented paired analysis, limiting the study to aggregate trends. Finally, the study assessed short-term interest and engagement, but did not assess long-term outcomes such as persistence in the ChemE major, academic performance in subsequent courses, or career pathways.

III. Future Work

Analyzing Spring 2025 data will be a critical next step in understanding the impact of PORPs. The extra credit incentive is expected to increase start-of-semester survey participation, thereby improving statistical power and enhancing the robustness of parametric analyses. Comparing fall and spring end-of-semester interest in ChemE subfields will clarify how interest evolves when subfields incorporate PORPs versus traditional recitation problems. Additionally, a larger sample size and greater diversity of responses will enrich the qualitative themes, deepening insights from additional open-ended survey data and the second focus group.

To assess PORPs' impact on ChemE student retention, major declaration data for 2024–2025 will be collected in Spring. Given the seven-year decline in ChemE declarations at the study institution, tracking declaration rates after PORPs' implementation will indicate whether this intervention positively influences students' decisions to pursue ChemE.

Although academic performance data was gathered, this study did not focus on PORPs' impact in that area. Future research could explore the relationship between the use of PORPs in a course topic and the academic outcomes in those course topics. Survey data on students' perceived skill development in Intro ChemE could also be linked to specific learning outcomes and academic performance. Comparing trends in self-efficacy and interest with objective measures, like enrollment and academic performance, could address self-reporting bias and enrich understanding of how students' perceptions align with measurable outcomes.

To address study limitations, future research should involve multiple institutions with larger, randomized samples. Expanding to institutions of varying size, geographic location, and demographics will be essential for understanding the intervention's broader impact on diverse student populations and validating the modified instrument across different settings. Additionally, a fully controlled experimental design—such as multiple course sections with randomized assignment—would strengthen causal inferences regarding the effectiveness of PORPs.

Studying PORPs across different engineering disciplines would help assess the transferability of this approach. Future work could also include longitudinal tracking of students' academic performance and career trajectories, clarifying the intervention's long-term effects. Finally, integrating "people-oriented" learning activities into labs, projects, or lectures would offer valuable insights into how this pedagogical strategy can enhance learning in other contexts.

Conclusions

This study highlights the potential of PORPs as a recitation intervention to foster greater student interest and engagement in ChemE. In the introductory chemical engineering course studied, the two topics that incorporated PORPs had the highest end-of-semester average interest. This finding demonstrates the value of contextualizing recitation problems with relevant faculty research. By linking course content to current faculty research, PORPs helped students see broader ChemE applications and career opportunities, which could help address challenges related to student retention. While trends in career interest and outcome expectations were promising, further research is needed to understand the long-term impact of PORPs on student retention and academic performance.

Focus groups provided further evidence of PORPs' effectiveness in improving student engagement, with many students excited to learn about faculty research and career paths. However, reactions were mixed on balancing technical and contextualized content—some students wanted more technical examples, while others prioritized exposure to the field and department. These differing perspectives highlight the challenge of integrating novel interventions within diverse student expectations and time-limited curricula. Future iterations of PORPs will need to strike a balance between contextualization and technical rigor to maximize its impact on student learning and interest in ChemE.

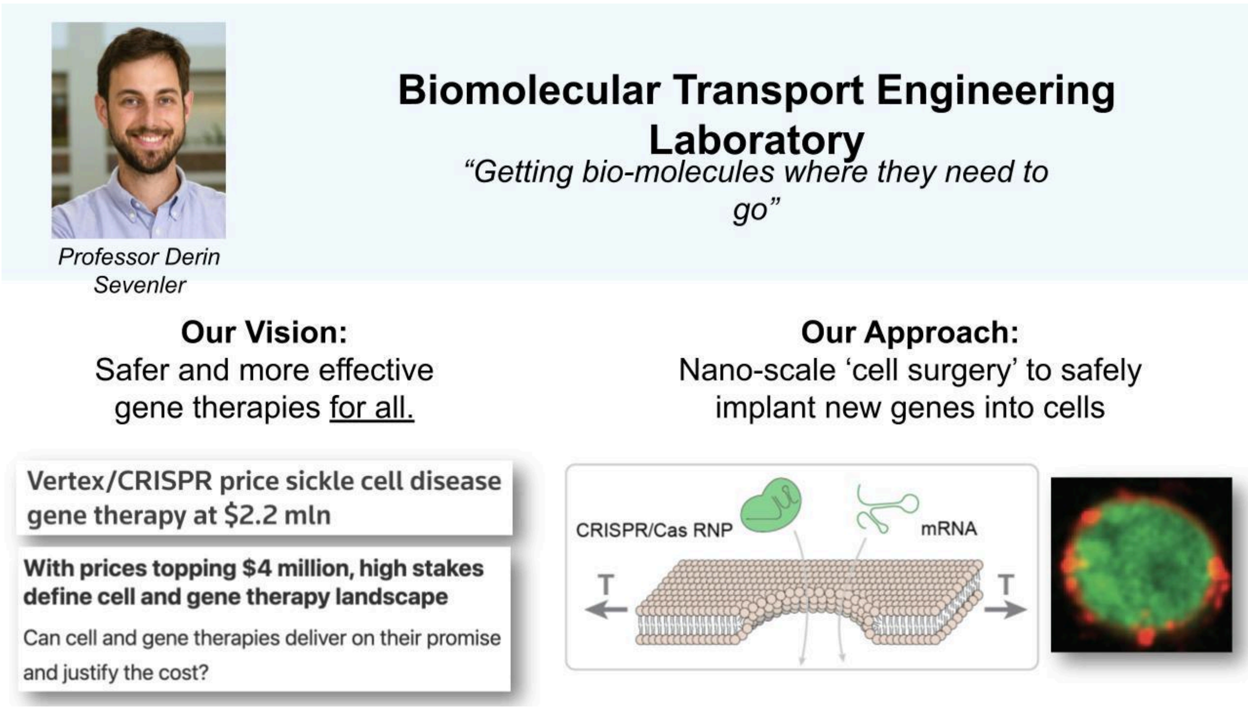
Looking ahead, continued data analysis from subsequent semesters will provide deeper insights PORPs' long-term effects on ChemE retention, academic performance, and major declaration rates. Future studies should expand the sample size, incorporate multi-institutional comparisons, and investigate PORPs across various engineering disciplines. As ChemE educators seek innovative ways to engage and retain students, interventions like PORPs offer valuable insights into how contextualized learning can shape students' perceptions of the field and their future career prospects.

Institutional Review Board Considerations

This study, titled "Impact of People-Oriented Recitation Problems," was reviewed and determined to be exempt under the 2018 Common Rule 45 CFR 46.104.d by the Carnegie Mellon University Review Board (IRB). The exemption was granted on August 26, 2024, under categories (1) educational settings and (2)(i)-(iii) tests, surveys, interviews, or observation. Limited IRB review was conducted where necessary, ensuring compliance with ethical research standards. The study's IRB determination is registered under STUDY2024_00000306, and documentation of the exemption is retained for reference. This determination of exemption does not expire, and the study will remain active until formally closed by the principal investigator. All study activities were conducted in adherence to Carnegie Mellon University research policies, including the responsible conduct of research.

Appendices

Appendix I. Example People Oriented Recitation Problem Faculty Slide



Appendix II. Start-of- and End-of-Semester Survey Items.

Item Number	SCCT Aspect	Item
1	Self-efficacy	I am able to do well in chemical engineering classes.[a]
2	Self-efficacy	After I graduate, I will be able to get a job as a chemical engineer.[a]
3	None[b]	I know the type of work that chemical engineers do.[a]
4	Outcome Expectation	If I learn a lot about chemical engineering, I will be able to do lots of different types of careers.[a]
5	Outcome Expectation	Carnegie Mellon University's chemical engineering courses will prepare me to succeed after I graduate.[a]
6	Choice Goal	I plan to be a chemical engineer in the future.[a]

7	Interest	I am interested in careers that involve chemical engineering.[a]
8	Interest	I like the work that chemical engineers do.[a]
9	Interest	Air Quality & Climate[c]
10	Interest	Biotechnology & Pharmaceutical Engineering[c]
11	Interest	Energy, Decarbonization, & Sustainability[c]
12	Interest	Process Systems Engineering[c]
13	Interest	Soft Materials & Complex Fluids[c]

[a]Item choices were on a Likert-scale, 1 (strongly disagree), 2 (disagree), 3 (neither agree nor disagree), 4 (agree) and 5 (strongly agree)

[b]This item measures 'Understanding of Field' for ChemE and does not correspond directly to SCCT

[c]These items prompt respondents to "Rate your interest level in the following chemical engineering fields:" with an interest scale, 1 (not at all interested), 2 (slightly interested), 3 (somewhat interested), 4 (very interested) and 5 (extremely interested)

Appendix III. Focus Group Questions in Order

- Can you describe your overall experience of the Intro to Chemical Engineering course?
- What were some of the things that you found exciting while taking the Intro to Chemical Engineering course and why?
- What were your thoughts on how time in class was spent? Would you change anything?
- What learning activities did you like the most and why?
- What learning activities helped you feel most confident in your chemical engineering abilities and why?
- What are your opinions on the recitation problems that were introduced with a faculty member slide?
- Were there specifically faculty members' slides or videos that were of particular interest to you or that you found particularly memorable?
- Would you change anything about the recitations, if so what would you change?
- What do you hope to gain out of pursuing and attaining an engineering degree?
- Did you find anything surprising while taking the Intro to Chemical Engineering Course?
- What were some of the biggest challenges you have experienced in studying engineering?
- Is there anything else you would like to share about the Intro to Chemical Engineering Course that we missed in our conversation?

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