

WIP: Preparing Incoming Chemical Engineering Graduate Students from Varying Academic Backgrounds for Graduate Level Curriculum through Peer-Led Workshops

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Introduction

Incoming graduate students into the Chemical Engineering Department at Northwestern University come from a variety of educational and personal backgrounds. Although several studies have assessed how race, ethnicity, and gender impact students' sense of belonging within STEM departments [1], [2], the impact of educational background on incoming graduate students' sense of confidence and belonging is understudied. Educational background can include factors such as differing undergraduate degrees (i.e., Chemistry vs Chemical Engineering), time off between undergraduate and graduate degrees, or exposure to US institutions of higher education vs international institutions. These factors may come into play during the first term of graduate school, where the lack of familiarity, feeling of being “othered,” and feelings of being unprepared may lead to poor performance in coursework and a negative impact on a student's sense of belonging in the field and department [1], [3].

Previous research focused on graduate students at the University of California, Berkeley Chemistry Department found that investment in education, peer relationships, and faculty relationships are the main drivers of student belonging [1], [3]. Further, around 2/3rds of the graduate students reported feeling imposter syndrome, or a “feeling of inadequacy in comparison to one's peers”. The University of Wisconsin, Madison's chemistry department developed programs to give students individualized support in coursework during their transition period to a PhD program [5]. They argued the need for programs to support student academic success and sense of belonging as they begin graduate school. While interventions aimed at supporting transitions to undergraduate programs have been proven successful [6], [7] fewer programs have been introduced for the graduate population [5]. Interventions for the graduate student population primarily target research skills, but neglect coursework preparedness [8]. Further, peer-led interventions generally show a positive correlation with student performance and confidence in their coursework [9], [10]. Supporting graduate students' academic success during the PhD transition presents a relatively untapped opportunity to improve student confidence in chemical engineering course material and sense of belonging.

In this work-in-progress study, we examine two cohorts of incoming chemical engineering graduate students and investigate how peer-led mini-courses tailored to core chemical engineering courses, specifically in calculus and differential equations, coding, kinetics and thermodynamics, and transport before the start of the students' first term can increase students' sense of confidence in their ability to complete coursework and belonging in the program, and how this differs by educational background. Our results suggest that students' educational background does not meaningfully impact their confidence in coursework when entering graduate school. After the peer-led mini-course intervention, students' sense of belonging in the department increases, although their confidence to complete their coursework decreases after the first term of coursework, regardless of educational background. Ultimately, we hope to use this work to design and improve interventions that ensure all students have both the tools to be successful in graduate school and a sense of belonging in the department.

Program Description

Course Structure

Mini-courses were designed as a chemical engineering coursework refresher for students before the start of the fall term. We particularly encouraged instructors to focus on key topics which students may have seen in undergraduate coursework, and which recur in graduate courses. Courses were offered to students one week before the start of the fall term. The courses were entirely optional and advertised to students via email. Each course was structured to be 1 hour with a suggested outline of 30 minutes of course material and 30 minutes of questions. These courses were only offered in person, but all the materials were shared with all incoming students regardless of their attendance. We collected survey data before and after the mini-courses, and upon the students' completion of their first term of coursework (**Fig. 1**). Course offerings included Calculus and Differential Equations, Coding, Kinetics and Thermodynamics, and Transport. These directly align with the courses that incoming students are required to take in their first year of graduate school (i.e. Thermodynamics, Math, Transport, and Kinetics), and the coding class covered basic coding skills which are applicable across many of the first-year courses.

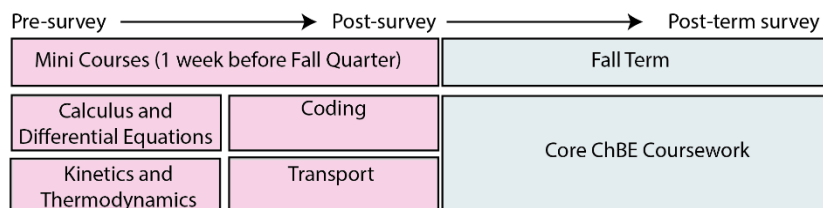


Figure 1: Mini- courses and timeline of surveys administered in this study.

Peer Instructors

Mini-courses were facilitated by graduate students on the department's Accessibility, Ableism, and Mental Health Committee. We solicited mini-course instructors via email and asked interested graduate students and post-doctoral researchers to fill out a survey detailing which course(s) they were interested in. Instructors were a mix of PhD students and post-doctoral researchers in the department. Any current member of the department was eligible to volunteer for this initiative. Instructors were not financially compensated for their participation; however, they were recognized in the department newsletter for their contributions. There were two instructors assigned to each course. We conducted a brief 30-minute training with instructors to go over course expectations, provide past course materials, and share best practices on active learning through practice problems and group work.

We obtained permission from the instructors to share their course materials with all incoming first-year students (regardless of their mini-course attendance) after all the courses were completed. Instructors for the second iteration of this initiative were given access to the previous year's course materials. We assessed instructor motivation for volunteering to teach a mini-course and found a variety of responses, related to improving communication skills, contributing to the department community, and gaining teaching experience. This illustrates that this initiative may be a good way not only to support incoming students, but also to give current students the opportunity to gain teaching experience and build community, which have been shown to be beneficial to student confidence [11], [12].

Results and Discussion

Student Motivation for Participating in Mini-Course Series

We first explored students' motivation for participating in the optional mini-course series. We hypothesized that those with a non-traditional Chemical Engineering (ChE) background (i.e. taking time off between undergraduate education and graduate education or completing a non-ChE undergraduate degree) would be interested in the mini-course series to refresh ChE concepts that might be more front-of-mind for students progressing directly to graduate school. We found that regardless of educational background, the primary reasons for attending the mini-courses were to review ChE topics from undergraduate programs, build community with peers, and make sure to get all relevant resources before starting coursework, demonstrated by the responses skewed toward “strongly agree” (**Fig. 2**). Students were less motivated by learning material they didn't focus on in undergrad and supplementing their non-ChE coursework, demonstrated by the broad distribution of responses. **Fig. 2** shows that overall, students' motivations for participating in the mini-courses remain consistent before and immediately after the courses, potentially indicating that the content and impact of courses met students' initial expectations.

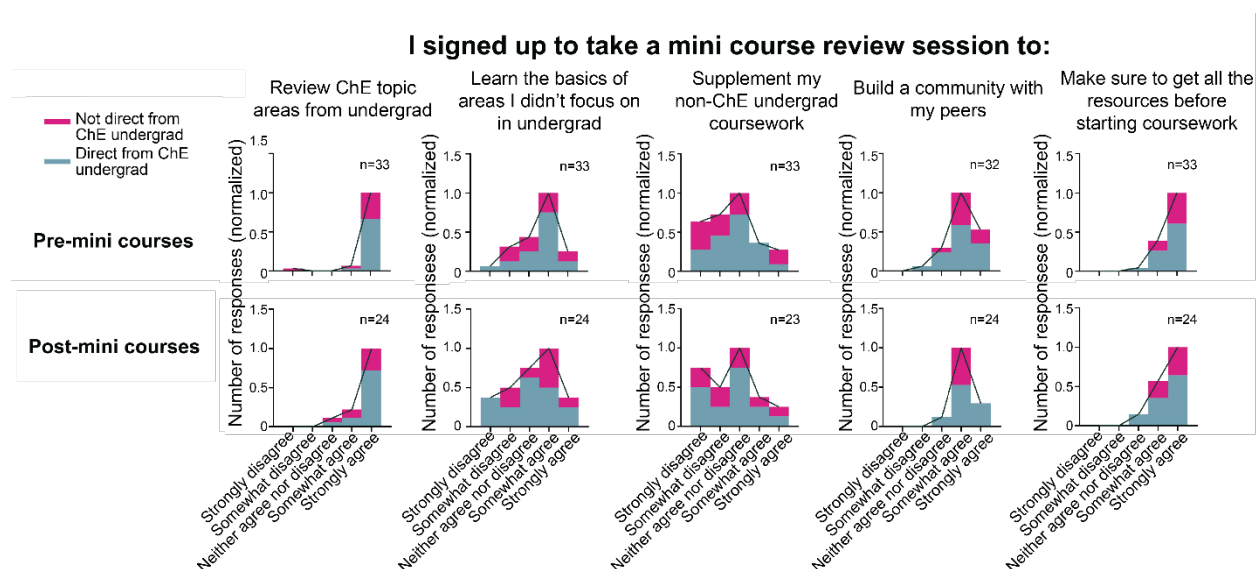


Figure 2: Survey results on the students' motivation for taking one (or more) mini-course(s). Normalized by most frequent response.

Each survey included space for additional comments. In the pre-survey, some students used this space to expand on their motivations for taking the course. One student who took time away from school between their undergraduate degree and this graduate program noted: “My main concern with classes is that it's been about 5 years since most of my undergraduate classes and I'm really rusty on my engineering and math.” Another student noted that they were “excited, I think it's imposter syndrome getting to me,” indicating there may have been a desire for the mini-course intervention to build confidence in their ability to complete ChE coursework and community.

Impact of Mini-Course Intervention on Student Confidence

In assessing student confidence before and after the mini-courses and after their first term of graduate school, we asked a series of questions related to students' confidence in their ability to learn and complete the coursework in core ChE courses (**Fig. 3**). We found no meaningful difference across the surveys between students with and without a ChE undergraduate degree, indicating that students without a ChE undergraduate degree feel prepared to tackle ChE coursework. Further, we found a decrease in negative responses related to students' confidence after completing the mini-courses, demonstrated by fewer "Not at all confident" and "Slightly confident" responses across all the questions. This indicates that the mini-courses were successful in improving students' sense of confidence in coursework going into their first term. However, upon completion of the first term, we see a negative trend in confidence across all of the questions, where the distribution of responses is more negative than the pre-survey. We note the greatest decrease in confidence for the last two questions, which pertain to student confidence in learning all the material presented to them in their ChE courses and in completing the hardest work assigned to them in their courses, respectively. Ultimately, this data indicates that further interventions or changes to the graduate student program may be necessary to maintain student confidence in completing ChE coursework during the first term.

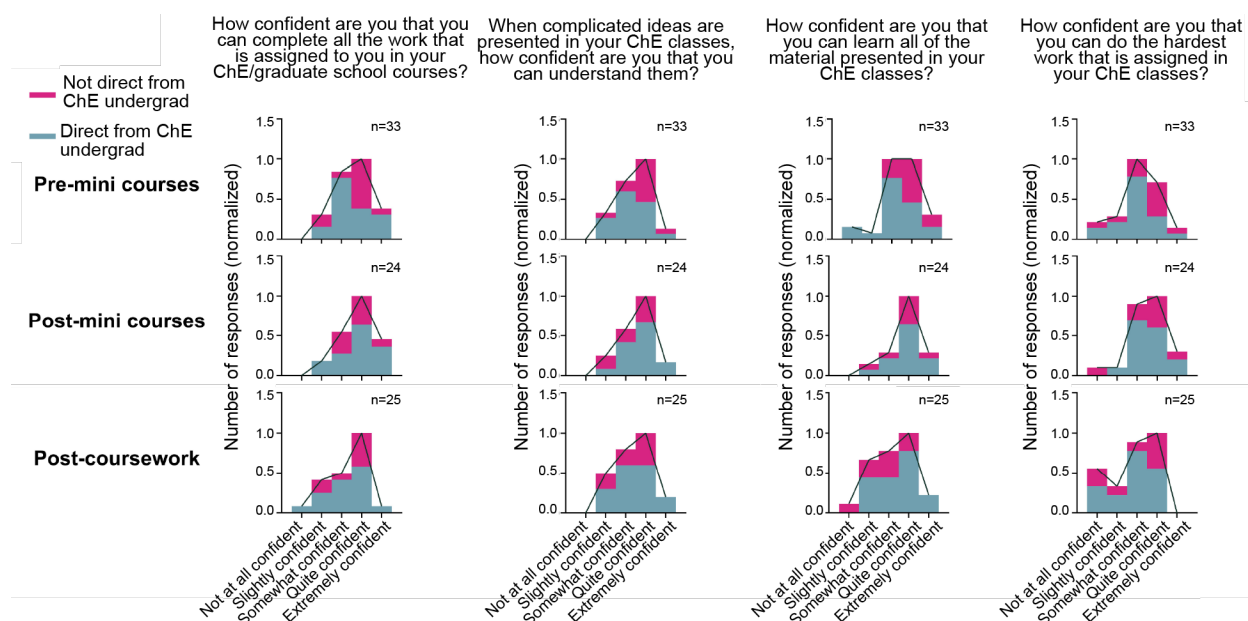


Figure 3: Pre- and post- mini-course and post-term survey responses related to student confidence in completing graduate school coursework. Normalized by most frequent response.

Impact of Mini-Course Intervention on Student Sense of Belonging

To explore the effect of the mini-courses on students' sense of belonging, our surveys included a series of questions regarding the students' feelings of connectedness, respect, and welcoming in the department (**Fig. 4**). The proportion of student responses indicating positive feelings of belonging either stayed the same or increased slightly after participating in the mini-courses, indicating that students may not feel significant increases in their feelings of belonging after only a few hours with their new peers. After one term of coursework, however, the surveys indicate that the students feel that people in the department understand them better, as evidenced by the increase in the proportion of "Understand quite a bit" responses. In addition, most students appear to feel

more connected to the people in the department, shown by the increase in the proportion of “Quite connected” responses.

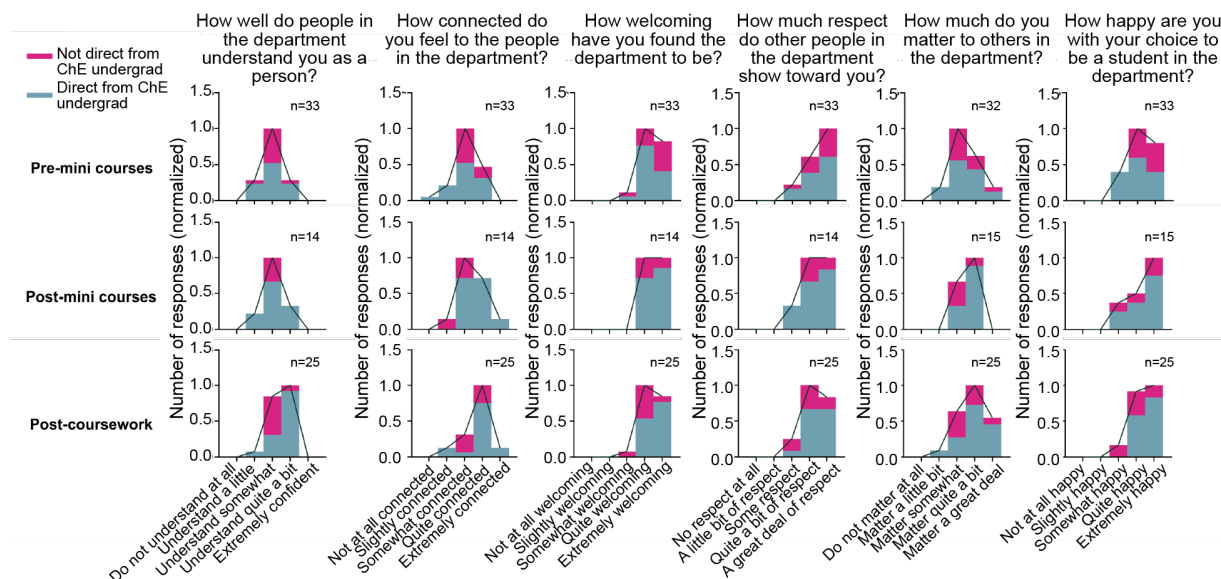


Figure 4: Pre- and post- mini-course and post-term survey responses related to student feelings of belonging in their graduate school program. Normalized by most frequent response.

In addition, we see that throughout the study, students felt primarily positive feelings of belonging in their graduate school program, with similar response trends between those who came directly from a ChE undergraduate program and those who did not. In particular, students rate their happiness with their choice to be a student in their graduate school program especially high, even after a term of coursework. Overall, these results indicate that the mini-courses do not directly increase feelings of belonging in graduate school, but feelings of belonging continue to improve after the fall term has been completed. These findings present the opportunity to further develop the mini-courses with a stronger focus on community building.

Strengths & Opportunities for Improvement within the Mini-Course Series

The post-course survey had space for written responses on the strengths of the mini-courses and suggestions for improvement. Students felt that the courses and instructors were particularly strong in explaining basic concepts and including worked examples. Comments highlighted that the “explanations were clear,” the courses had a “good split between example and explanation,” and focused on “how to break the problems down and solve them.” Students appreciated when instructors provided follow-along notes or workbooks at the start of the course, especially in the coding course, where instructors provided an interactive Google Collab notebook. One student noted that “the interactive workbook was beneficial because we can follow along and implement the code ourselves,” and another noted that the workbook could be “a resource for basic things that come up often.” These responses indicate an opportunity to incorporate more follow-along examples in other subjects. To improve the courses, students desired more worked problems and connections between basic ChE concepts to what they might be presented with in their graduate coursework, indicating an opportunity to introduce more advanced topics. One student noted the coding class could be improved by “emphasizing how and when we need to code in our coursework,” and another noted that the transport class could “give a preview of what the math will look like in the grad-level class.” These courses were limited by time and intended to focus

on the basics, but perhaps future iterations could be expanded to include more material and clearer connections to upcoming coursework.

Conclusions and Future Work

In this study, we examined the impact of peer-led mini-courses on student confidence in completing ChE coursework and belonging during their first term of a graduate ChE program. We conclude that students were motivated to take the courses by the opportunity to review ChE topics and resources and build community, and we find an increase in overall confidence immediately after the mini-courses. However, this confidence boost fades after completion of first-term classes. Although we did not explicitly ask students to explain any decrease in confidence in the surveys, we hypothesize that while the mini-courses were effective in increasing student confidence going into the term, ultimately, the stress of completing graduate-level coursework while adjusting to graduate school negatively impacted student confidence [13], [14]. These results suggest that a decline in confidence may be systemic rather than individual and continued interventions may be needed during the first term to counteract this trend. We note that feelings of belonging moderately increase after the mini-courses, but increase more significantly after a term of classes, suggesting increasing time spent with peers is more impactful than the mini-courses. We see minimal differentiation between students with a direct transition to the ChE graduate program and those who spent time away or received a non-ChE undergraduate degree. While we attempted to pair pre- and post-course data by individual participant, there was enough discrepancy in the participant-provided anonymous codes that only we could only accurately pair a few sets of responses and thus did not include this analysis. Students noted the inclusion of worked examples and explanations of basic topics as course highlights, and future iterations should draw more explicit connections between mini-course topics and coursework and include more time for community building to boost students' sense of belonging. We will continue collecting data on this program for another year, after which we hope a larger dataset will allow us to include paired data and more robust statistical analysis, including t-tests, of observed trends. We believe this framework of peer-led mini-courses is adaptable to many subject areas and encourage other institutions to adopt such early interventions in an effort to improve graduate student confidence and belonging across educational backgrounds.

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