Implementation of a Pre-Course for Organic Chemistry I to Improve Student Course Outcomes

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Introduction

- Organic chemistry is often considered one of the hardest gateway courses for STEM majors, and it builds on general chemistry.
- Lack of foundational chemistry skills from general chemistry, large gaps of time between taking general chemistry and organic chemistry, and low self-efficacy are possible contributors to poor performance in organic chemistry courses[1] .
- Equity gaps in chemistry have been described for women, first-generation, and persons historically excluded from STEM due to ethnicity or race (PEERs)
- The DFW rate at UNL from Fall 2018 to Spring 2020 was 16% with a 7% equity gap for first-generation students and 9% for PEERS.

Literature Review & Context

- Pre-courses for organic chemistry have the potential to increase student confidence and help students review material critical for success:
  - A 3-week pre-course reviewing general chemistry improved outcomes for at-risk student populations.[1]
  - A 6-week hybrid course reviewing general chemistry decreased self-reported anxiety levels for students[2].
  - A video library for an organic chemistry lab increased self-concept of experimental work in users who frequently viewed the videos[3].
- Class observations from homework during AY 2020-21 revealed that students struggled to incorporate pre-requisite knowledge and that the small review at the beginning of the semester was not sufficient.

Figure 1: Just-in-time teaching response from Week 12

Research Questions

1. Are the background characteristics of students who enroll in the pre-course different from those that do not? Do those characteristics differ by semester?
2. Does participation in the pre-course improve course outcomes?

Methods

Pre-course design:

Optional, asynchronous prerequisite review course created.

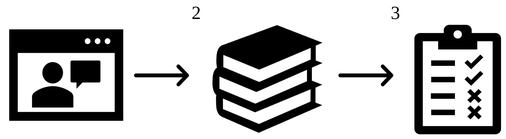


Figure 2: 15 Skill Pre-Course Sequence with Video (1), Reading/ALEKS module (2), and Quiz (3)

Data collection:

During AY 2021-2022, all students (n=555) enrolled in regular course participated in the following as a part of their course grade (only students' consenting to participation have results reported, n = 481).

- Self-confidence, self-efficacy, belongingness, and engagement survey[4,5]
- Demographics survey
- General chemistry skills assessment (GCSA)

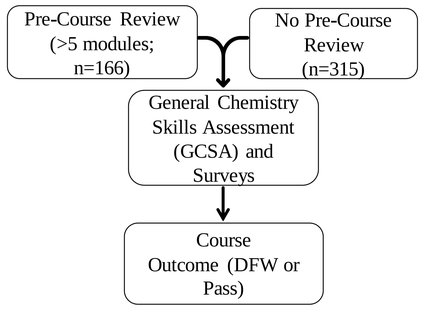


Figure 3: Timeline of Data Collection with Pre-Course Review (3 weeks before start of semester), GSCA & Surveys (1st week of semester), and Course Outcome (Week 16)

Statistical Analyses:

- All statistical analyses were conducted in SPSS version 28.
- One-way ANOVA tests were used to describe background characteristics of students enrolled in pre-course and to compare fall and spring students.
- Case control matching of pre-assessment score, pre-engagement score, and first-generation status was conducted to assess effect of pre-course on course outcome.

Results

RQ1. Do background characteristics of enrolled vs non-enrolled students differ? Do those characteristics differ by semester?

Fall 2021: enrolled vs non-enrolled students were similar in gender, race, first-generation status, working status, self-efficacy, and belongingness. They **differed** in engagement and confidence.

FA & SP Populations Differ

Fall 2021	Enrolled (n = 124)	Non-enrolled (n = 231)
Percentage	35%	65%
Mean Engagement Score*** **(p<0.001)**	4.2	4.0
Mean Self-Confidence Score* **(p=0.041)**	3.9	3.8

Spring 2022: enrolled vs non-enrolled students were similar in gender, race, working status, self-efficacy, confidence and engagement. They **differed** in first-generation status and belonging.

Spring 2022	Enrolled (n = 42)	Non-enrolled (n =84)
Percentage	33%	67%
First Generation Status***(p=0.014)**	17%	38%
Mean Belongingness Score***(p=0.016)**	4.1	3.8
%DFW (p=0.393)	4%	12%

Enrolled vs non-enrolled have lower DFW rates (p = 0.022). Enrolled students are different, and there are general differences between leading and trailing course

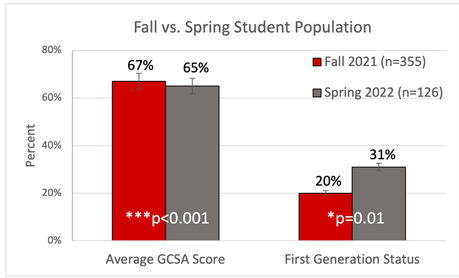


Figure 4: Students differ overall in GCSA score and first-generation status.

RQ2. Does participation in the pre-course improve course outcomes?

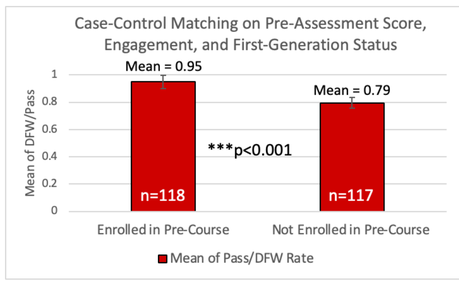


Figure 5: Matched students significantly benefit from pre-course.

Conclusion

- **Enrolling and completing 5 or more modules in pre-course significantly reduces DFW rate for students.**
- **First-generation, PEERs and students with low self-reported engagement benefit from pre-course.**
- **All enrolled PEERs passed the course (n =14; 0% DFW) versus non-enrolled (n = 37; 24% DFW).**
- **FA & SP and enrolled vs non-enrolled populations differ in characteristics. Case control matching provides a comparison.**

Future Directions

- Low racial and ethnic diversity prevented statistical comparisons of enrolled PEERs.
- Similar data was collected on the pre-course during AY 22-23. Adding two additional semesters of data will allow more robust comparisons and more matching.
- Improvements to the pre-course are being made in response (e.g., more review topics in Spring).
- Different pedagogies in the regular course could be used to engage students in Fall versus Spring semesters given differences.
- Findings from this study can help the general chemistry and organic chemistry sequences better align their curriculum.

Funding

This work was made possible thanks to funding from the Undergraduate Creative Activities and Research Experience (UCARE) at the University of Nebraska-Lincoln and a Pedagogic Intervention Grant from the Center for Transformative Teaching (CTT) at the University of Nebraska-Lincoln.

References

[1] Fischer, C., Zhou, N., Rodriguez, F., Warschauer, M., & King, S. (2019). Improving college student success in organic chemistry: impact of an online preparatory course. *Journal of chemical education*, *96*(5), 857-864.

[2] Pulukuri, S., Torres, D., & Abrams, B. (2021). OrgoPrep: A Remote Peer-Led Summer Program Preparing Students for Organic Chemistry. *Journal of Chemical Education*, *98*(10), 3073-3083.

[3] Pölloth, B., Teikmane, I., Schwarzer, S., & Zipse, H. (2019). Development of a modular online video library for the introductory organic chemistry laboratory. *Journal of Chemical Education*, *97*(2), 338-343.

[4] Marshman, E. M., Kalender, Z. Y., Nokes-Malach, T., Schunn, C., & Singh, C. (2018). Female students with A's have similar physics self-efficacy as male students with C's in introductory courses: A cause for alarm?. *Physical review physics education research*, *14*(2), 020123.

[5] Yorke, M. (2016). The development and initial use of a survey of student 'belongingness', engagement and self-confidence in UK higher education. *Assessment & Evaluation in Higher Education*, *41*(1), 154-166.

Old Text

- Pre-Course Components:

- Optional and approximately 3 weeks prior to semester, students who wished to participate in pre-course filled out survey to indicate interest and were added to Canvas course

- 15 general chemistry skills tested with increasing difficulty and complexity

- Students could not move onto next module until previous one was completed

- 3 step module consisting of watching a video, reading the textbook, and taking a mastery quiz over the skill

- Mastery test of all 15 skills given at end to test retention

- Incorporation of Surveys into Semester Course Points:

- 5-point Likert survey evaluating self-confidence, self-efficacy, belongingness, and engagement4,5 .

- Survey also asked for demographic data such as major, gender, if they participated in the pre-course, and if they would like their responses to be utilized for research

- Figure 5: Matched students significantly benefit from pre-course

- Organic chemistry is generally considered one of the hardest essential gateway courses for STEM (science, technology, engineering, and math) majors. Lack of foundational chemistry skills from general chemistry, large gaps of time between taking general chemistry and organic chemistry, and low self-efficacy are all possible contributors to poor performance in organic chemistry courses1 . Underrepresented populations in STEM may fear they are not capable of performing well and shy away from entering STEM-related fields as a result.

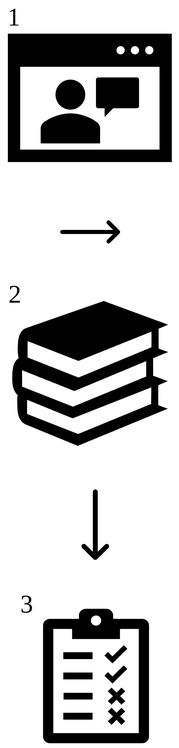
- Due to the nature of organic chemistry building upon these critical skills and integrating new knowledge and skills on this foundation, understanding the gaps in knowledge on specific topics is key. Strengthening these skills can not only be beneficial for performance in organic chemistry, but in feelings of self-efficacy and confidence of the student.

- In the past five years, the number of online courses and content has increased dramatically, particularly around the time the pandemic occurred. The movement back to more in-person courses can be anxiety inducing and many students may feel underprepared in their skills, particularly if they have only seen some of these concepts once.

- Therefore, pre-courses for organic chemistry have become a target of research in the past couple of years. One study using a 6-week hybrid structure course reviewing relevant topics from general chemistry found decreased self-reported anxiety levels for students who utilized the pre-course2 . The use of a video library for an organic chemistry lab increased self-concept of experimental work in users who frequently viewed the videos, emphasizing even further the benefit of a pre-course for UNL students3 .

- During the Fall 2020 and Spring 2021 semesters, which were largely online, small homework assignments were given live in class and submitted for feedback. These submissions revealed that students struggled to incorporate pre-requisite knowledge and that the small review at the beginning of the semester was not sufficient.

Diagram Options



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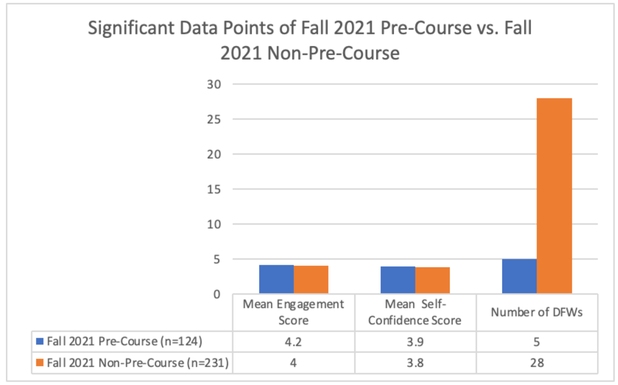

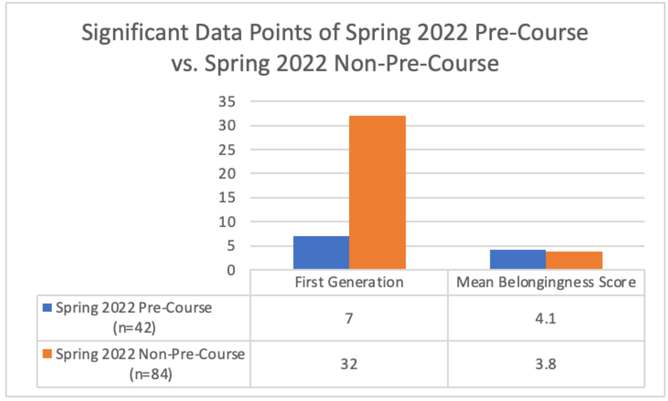

Significant Data Points	Fall 2021 Pre-Course (n=124)	Fall 2021 Non-Pre-Course (n=231)
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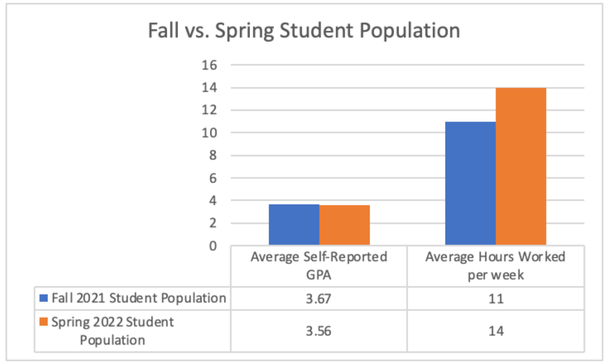

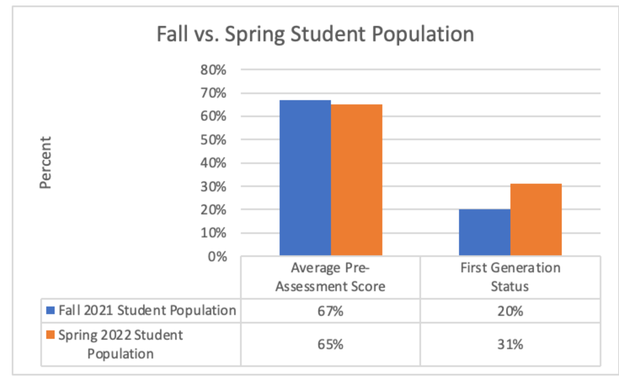

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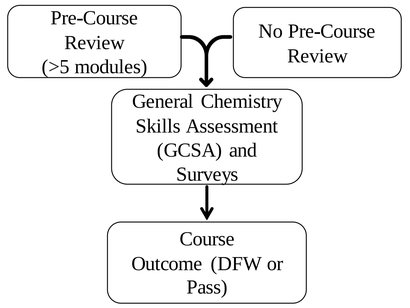

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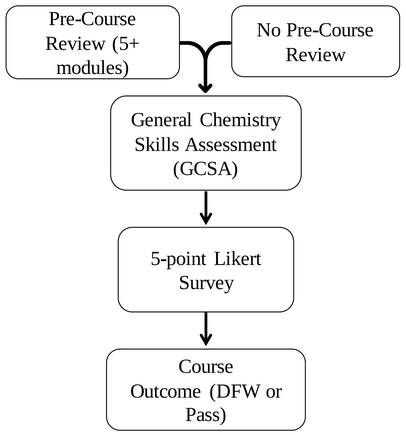

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Though this study did not find statistically significant gains for PEERS students taking the pre-course, there are still valuable considerations of this population to make. The overall number of PEERS students was quite low for both semesters which could mean there was simply not a large enough sample size of this subset of students to examine. Therefore, gaining more data is essential to seeing if there are any statistically significant gains for PEERS students.

In addition, adjusting the pre-course to be more beneficial for Spring students may be valuable to creating an overall better organic chemistry experience. High self-reported engagement, low self-reported belongingness, and continuing-generation students seemed to benefit most from the pre-course, however, many students who took the pre-course indicated that it was helpful on brushing up on old skills and topics from general chemistry.

Collecting more data is the prime future direction so that numerous Fall and Spring semesters can be compared to see if the pre-course benefits are similar or dissimilar across differing student populations. Greater data collection can also help in creating more specific review content as if many students are struggling with the same material each semester, it could help create better emphasis on these topics in the original general chemistry sequence. In addition, adaptations to the pre-course for Fall and Spring populations to increase the gains Spring students may have from the pre-course is also another goal.

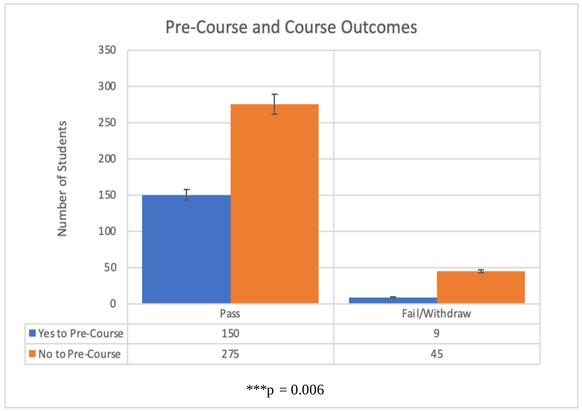
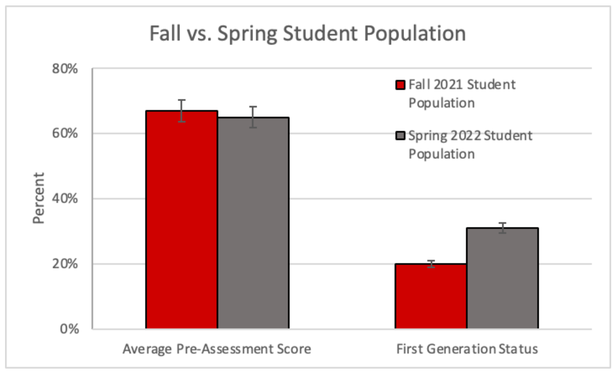
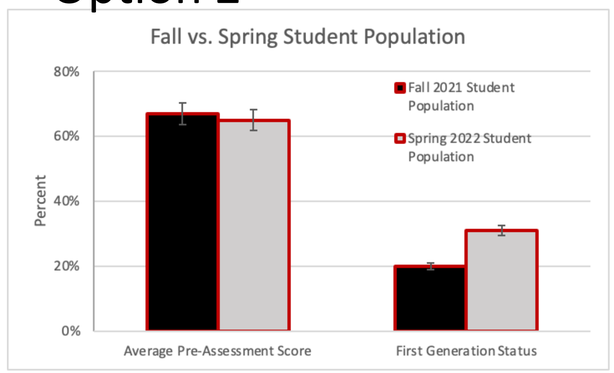


Figure 4: Pre-Course Option and Course Outcome Graph

Option 1



Option 2



Option 3