

Academic Success Skills in First-Year Chemical Engineers: A Before and After Look at the Pandemic

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Abstract—The introductory chemical engineering course for first-year undergraduate students at the University of Rochester includes workshops focused on building success skills to help students persist academically in the major. The instructor of these workshops has administered Landis' Academic Success Skills Survey during the fall semester since 2015, including Fall 2020, to better understand how the workshop activities and assignments contribute to students' academic success as future chemical engineers. In this Innovative Practice Full Paper, we compare students' pre-post course results related to self-perceived improvements in their academic success skills between the Fall 2019 semester (a regular in-person semester) and the Fall 2020 semester (a hybrid remote/socially-distanced semester). In Fall 2020, students' normalized gains in overall perception of their success skills were larger, students perceived more statistically significant improvements on individual success skills, students attributed more of their improvements to the course itself, and students' opinion of the University remained constant compared to Fall 2019 (i.e., the hybrid semester did not result in a more negative attitude about the University). Students also self-reported feeling a sense of community with their peers and faculty in the course, which indicates that the course may have been a vital cornerstone not only to students' overall academic careers in chemical engineering, but also to their resilience in the face of a uniquely challenging semester during a global pandemic. Based on these results, we offer detailed descriptions of the activities and assignments of the workshops for other first-year engineering instructors to consider for their own courses moving forward.

Keywords—Fall 2020, hybrid, remote, socially-distanced, comparison, chemical engineering, introductory

I. BACKGROUND AND INTRODUCTION

The move to emergency remote instruction during the Spring 2020 semester marked the beginning of a unique year of teaching and learning. Unfortunately, some of the most significant student outcomes from the interrupted semester appear to be declines in mental health [1]. As news about Covid-19 increased, people began to be more sedentary, more anxious, and more depressed [1]. An unexpected shift from in-person social interaction to almost solely online [2] only served to compound the stress for faculty and students alike. Students at the University of Rochester, specifically, saw stark declines in their mental health between 2018 and 2020 on the National College Health Assessment [3]. Although the summer is often a time to recharge and refresh, the summer of 2020 was dominated

by concern for the worsening pandemic conditions, the US presidential election cycle, and, for college instructors in particular, how to improve in the fall from their disrupted courses in the spring. Much of this restructuring centered on video conferencing software like Zoom and how to facilitate students' engagement online [4]. Although many instructors found ways to restructure their in-class discussions and small group activities to fit the hybrid remote/socially-distanced teaching landscape, hands-on activities like labs and team projects in engineering remained a challenge [2].

Student outcomes from the academic success workshops in a course called "Sustainable Energy" (CHE 150) for first-year chemical engineering students at the University of Rochester have been reported for five consecutive fall semesters (Fall 2015, 2016, 2017, 2018, and 2019) [5]. In this study, we seek to expand on that previous work by exploring differences between student outcomes from those workshops during the most recent regular in-person semester (Fall 2019) and the hybrid remote/socially-distanced Fall 2020 semester. Specifically, we examine how restructuring of hands-on activities and team-based social interactions affected students' self-perceived academic success skills against a backdrop of overall worsening mental health.

Based on the changes between the Fall 2019 and Fall 2020 semesters, the authors ask the following research questions in this study:

- How do workshops targeting critical academic success skills for engineers affect students' perceptions of those skills across in-person and hybrid formats?
- What academic success skills were well-targeted by the in-person and hybrid offerings of the course?
- How do the offerings differ in addressing the academic success skills based on students' perceptions?

II. INNOVATIVE PRACTICE INTERVENTION

Regardless of format, workshops in CHE 150 have included activities and reflective essay assignments drawn from Landis' text on academic success in engineering [6]. In the past five years, Landis' work has been used to inform engineering teaching and learning in higher education in the context of bridge programs [7], first-year engineering courses [8-9],

systemically marginalized students in STEM [7, 10], and even capstone courses [11]. For the first-year engineering context in this study, students were encouraged to visit professors as a part of assignments in the course, and some portion of class time was reserved each semester for University of Rochester professionals to share their experiences in STEM fields and raise awareness about available resources for engineering students specifically (e.g., the engineering library, career services, academic tutors, etc.). Classroom activities ranged from quick and straightforward team-building exercises to more formal laboratory exercises with assigned teams and peer evaluations. The course culminated in a final open-ended team design project to investigate the iterative nature of engineering design through a solar heating challenge in which students presented the struggles they faced and their resulting solutions orally. Together, these assignments and activities aimed to enhance the skillsets for students' ultimate success as future chemical engineers.

Because the workshop instructor uses feedback from previous semesters to continuously improve the students' skill-building experience, the Fall 2020 workshops included both more emphasis on student-identified problem areas from Fall 2019 and pandemic-related format modifications with lessons learned from teaching during the Spring 2020 semester. Fall 2019 CHE 150 students noted that in-depth discussion of chemical engineering practices and job opportunities could be improved and expanded upon, so the workshop instructor designed activities and assignments for the Fall 2020 semester that would introduce students to unit operation equipment (e.g. heat exchangers, fluid mixers, pumping devices, distillation columns, etc.) that can be found across multiple industries and for which upper-level chemical engineering courses provide additional context on their operations. This focus on unit operation equipment was chosen to provide continuity across the chemical engineering curriculum as well as more insight into industrial applications than previous semesters where the focus had been a more diffuse general introduction to engineering principles.

Moving from the in-person Fall 2019 semester into the hybrid Fall 2020 semester, Zoom breakout rooms were used because the typical physical space (large tables surrounded by 4-5 students for small group work) was unavailable due to social-distancing concerns. For example, during one class session, students were placed in breakout rooms to review and discuss video clips of various unit operation equipment related to aspects of chemical engineering and the roles of a chemical engineer in industry. Then, in a later class, student teams of 4-6 were tasked to find process flow diagrams incorporating multiple unit operations in a manufacturing process (i.e., cannabis extraction, pet food manufacturing, or petroleum processing) and describe them to the rest of the students in the course to reinforce the concept that these operations are employed across multiple industries. This preservation of the social connection of the course learning community via Zoom was also intended to maintain the evidence-based practices which are shown to support women and other systemically marginalized students in STEM. Additionally, this structure hoped to mimic the in-person sense of comradery that first-year first-semester students need to form a strong engineering

identity in their transition to college. Table I shows a more detailed listed of the differences between activities and assignments in Fall 2019 and Fall 2020.

TABLE I. CHE 150 WORKSHOP ACTIVITIES AND ASSIGNMENTS BETWEEN SEMESTERS

Focus/Skill Targeted	Fall 2019	Fall 2020
Team-based introductory engineering activity + oral presentation	Reverse engineer a solar-operated toy and provide brief oral presentation on findings and a chosen country's use of solar power (2-person team)	Review video clip on unit operation in breakout room; provide brief oral presentation on background, operation, and applications in industry; reflect via discussion board with peers
Community-building introductory engineering activity	Timed activity to build cost-effective tower from notecards in teams	Timed activity to identify and orally present a process flow diagram for an assigned manufacturing or processing industry in teams
Introduction to NAE Grand Challenges	Written assignment to review research of interest aligned with one of the Grand Challenges or of a department professor	Online discussion with upper-level students about their NAE Grand Challenge experiences followed by written assignment
On-campus resources guest lecture: career center	In-person visit with career center staff and upper level students, resume assignment with optional/informal upper-level student review and feedback prior to submission	Online breakout room discussions with career center staff and upper-level students, resumes reviewed online in discussion breakout rooms
On-campus resources guest lecture: engineering library	In-person visit by librarian to review online search engines, resources, and citation software and methodologies	Virtual visit from librarian to review online search engines, resources, and citation software and methodologies
On-campus resources guest lecture: diversity, equity, and inclusion	In-person visit from diverse group of upper-level students on the topic of what they wish they had known as first-years	Virtual visit by the director of the intercultural center, online discussions, breakout rooms, reflection via online discussion board with classmates
Introduction to computer programming languages	Arduino (basic, information to operate and run equipment for solar panel experiments)	Arduino (basic, as in Fall 2019) + 3-week introduction to LabVIEW programming [added in Fall 2020]
Career goals identification	Reflection essay	Reflection essay
Meet a department faculty member	Reflection essay	[omitted in Fall 2020]
Time management exercises	Reflection essays for two different assignments	Reflection essays combined into one assignment
Before/During/After class studying strategies	Reflection essay following proscribed exercises	Reflection essay following proscribed exercises
Introduction to CHE laboratories	Individual exercise to evaluate sources of power to heat water as precursor to team-based activity	Water-heating exercise with individually designed solar water heater, each student was provided or shipped a kit to use, written lab report
Multi-week iterative engineering design lab activity	Team-based process to create solar water heater, 3 hours of weekly supervised lab access time offered to students as option for 6 weeks prior to final oral team presentation with peer review	Individual process with lab access time unavailable due to social distancing [many students still found ways to collaboratively troubleshoot and debug while collecting data despite the restrictions]

New throughout the assignments for Fall 2020 was the use of online discussion boards as a part of the University of Rochester's available course management software, Blackboard. For participation credit, students were required to post their reflection of an activity (e.g., comment on three different unit operations, reflect on the implicit bias and racial inequity discussion, etc.). The modifications discussed in Table I above allowed remote learners to more fully engage with the course material and their teammates. The online posts generated the opportunity for students to comment back and forth on favorite pieces of equipment, previously unknown information, and appreciation for the particularly effective presentation styles of their peers.

III. METHOD

To explore changes in students' perceptions of their own academic success skills, CHE 150 students were surveyed using Landis' Academic Success Skills Survey [6] during the Fall 2019 and Fall 2020 semesters. The survey consists of 16 questions about academic success skills which students can respond to on a 5-choice "strongly agree" to "strongly disagree" scale (see [5] for additional details). In each semester, the survey was administered once in the first weeks of the course (pre-survey) and once at the end of the course (post-survey) so that changes in students' perceptions could be calculated. To quantify survey results, responses to specific questions were assigned point values. Responses of "strongly agree" yielded 2 points, "agree" 1 point, "neutral" 0 points, "disagree" -1 points, and "strongly disagree" -2 points, resulting in a possible range of scores from -32 (all "strongly disagree") to 32 (all "strongly agree"). Normalized gains between students' pre- and post-survey self-assessments were calculated using the average score for each cohort on each survey by the following formula:

$$NG = (post - pre) / (total\ possible - pre) \quad (1)$$

For both the total scores and individual item scores, average scores were calculated prior to calculating the normalized gain for the score (rather than calculating a normalized gain for each student individually and then calculating an average normalized gain for the cohort). A normalized gain of 1.0 would mean that students' perceptions changed such that they strongly agreed to all questions to which they had previously responded with less agreement. Students' scores were only included in the cohort averages if they completed both the pre- and post-surveys in a given semester, which resulted in a sample size of 30 (out of 41 total enrolled) in Fall 2019 and 19 (out of 43 total enrolled) in Fall 2020.

Because students were enrolled in multiple courses other than CHE 150 and students' perceptions may change for any number of reasons in their first semester, the course instructor designed a rating system to gauge students' perceptions of how significant the impact of specifically CHE 150 was on their skillset shifts. These rated questions were included on the post-survey only, and could be answered on a 3-choice "a lot/a little/none" scale.

For individual item score comparisons, significance was calculated using a Mann-Whitney U test for non-parametric data and a threshold of 0.1 (i.e., $p < 0.1$ was considered significant).

Effect size for significant differences was calculated using Cohen's D where the resulting value can be described as small, medium, or large based on standard values of 0.2, 0.5, and 0.8, respectively.

The study activities for which the results are reported in this manuscript have been approved by the UR Research Subjects Review Board (RSRB) ID#STUDY00003848.

IV. RESULTS AND DISCUSSION

A. Overall Normalized Gains

Fall 2020 students began lower and ended higher in their self-perceived academic success skillsets than in the Fall 2019 semester, with a normalized gain of 0.11 (see Table II). Based on the overall difference, Fall 2020 students at least "agreed" with 4 additional items (out of 16 total) by the end of the semester, while Fall 2019 students did not see much change. Even considering that students might be feeling pessimistic about the Fall 2020 semester as an explanation for the low pre-course ratings, those students still ended higher than Fall 2019 students post-course, which indicates that CHE 150 improved their self-perceptions during a challenging semester.

TABLE II. NORMALIZED GAINS FOR FALL 2019/FALL 2020 SURVEYS

Semester	Pre (out of 32)	Post (out of 32)	Difference	Normalized Gain (out of 1.0)
Fall 2020	11.8	15.8	4.0	0.11
Fall 2019	14.3	14.8	0.5	0.03

B. Impact of CHE 150

Overall, Fall 2020 students attributed at least "a little" of their improvement (on a scale of 0 = none, 1 = a little, and 2 = a lot) to their experience in CHE 150 to all but two items on the academic success survey:

1. *I am effectively managing the various aspects of my personal life, such as interactions with family/friends, personal finances, and outside workload. (average rating of 0.94)*
2. *I am aware of and make optimal use of campus resources such as the writing center, counseling center, student health center, library, and career center. (0.89)*

Further, six items received average ratings of 1.5 or above, indicating strong attribution of those items to the CHE 150 experience:

1. *I would give myself an A+ on the amount of time and energy I devote to my studies. (1.5)*
2. *I practice good study skills in areas such as note-taking and preparing for and taking tests. (1.7)*
3. *I recognize the importance of goal setting and I have clear academic goals. (1.6)*
4. *I am highly motivated through a clear understanding of the rewards graduating in my chosen major will bring to my life. (1.7)*

5. *At the University of Rochester, I know other students in my classes, and feel part of an academic learning community. (1.6)*

We note with particular interest that this item would be expected to be low based on the overall pandemic situation during the Fall 2020 semester.

6. *I feel good about the University of Rochester and about the educational experience I am receiving. (1.6)*

We note with particular interest that this item would be expected to be low based on the situation during the Fall 2020 semester.

In comparison, Fall 2019 students attributed less improvement to CHE 150 overall. While the same number of items were at least “a little” on the scale, only one reached the 1.5 threshold of attribution: “I practice good skills in areas such as note-taking and preparing for and taking tests. (1.5)” The two items that were rated lower than “a little” in Fall 2019 included one overlapping with Fall 2020, “I am effectively managing the various aspects of my personal life, such as interactions with family/friends, personal finances, and outside workload. (0.80),” and one new item, “I prepare for each lecture by reviewing my notes, reading ahead in the text, attempting some problems, and writing down questions. (0.97)”

Based on the results between the two semesters, Fall 2020 students seem to attribute more of the changes in their responses pre-post-course to their experience in CHE 150 than students in Fall 2019.

C. Individual Item Gains

When parsed out by individual items, some expected and unexpected results emerge from the comparison between semesters. These results are displayed in Tables III and IV below and include post-course average ratings, the difference between the pre- and post-course ratings (post – pre = difference), the p-value (if the pre-post difference met the threshold for significance; “ns” to indicate “not significant” otherwise), and the effect size of the difference (if significant). Values which have been bolded are higher between the two semesters, and values that have been blocked out in darkened cells indicate that both post-course average rating and pre-post difference were higher in that semester in addition to being significantly different between the start and the end of that semester. All effect sizes fell within the “small” range for this data set.

TABLE III. FALL 2020 INDIVIDUAL SURVEY ITEM ANALYSIS

Survey Item	Fall 2020			
	Post (-2 to 2)	Pre-post Difference	p-value	Effect Size
I interact regularly with my professors...	0.84	0.58	0.02	0.36
I make effective use of my peers...	0.89	0.68	0.03	0.35
I schedule my time...	1.2	0.16	ns	
...time and energy I devote to my studies...	1.1	0.26	ns	
I prepare for each lecture...	-0.16	-0.05	ns	
I keep up in my classes...	0.26	-0.05	ns	

Survey Item	Fall 2020			
	Post (-2 to 2)	Pre-post Difference	p-value	Effect Size
I...spend as much time on campus as possible.”	1.8	0.47	0.06	0.30
I practice good [study] skills...	1.5	0.16	ns	
...best methodologies for reading...	0.89	0.53	0.06	0.31
...I have clear academic goals.	1.5	0.11	ns	
I effectively manage...my personal life...	0.79	0.05	ns	
I am highly motivated...in my chosen major...	1.3	0.16	ns	
...feel part of an academic learning community.	1.1	0.47	0.07	0.29
I am aware of...campus resources...	0.58	0.11	ns	
I feel good about myself...	1.0	0.37	ns	
I feel good about the University...	1.3	-0.05	ns	

TABLE IV. FALL 2019 INDIVIDUAL SURVEY ITEM ANALYSIS

Survey Item	Fall 2019			
	Post (-2 to 2)	Pre-post Difference	p-value	Effect Size
I interact regularly with my professors...	0.70	0.07	ns	
I make effective use of my peers...	1.2	0.27	ns	
I schedule my time...	1.1	0.23	ns	
...time and energy I devote to my studies...	0.23	-0.20	ns	
I prepare for each lecture...	-0.07	-0.03	ns	
I keep up in my classes...	0.27	-0.13	ns	
I...spend as much time on campus as possible.”	1.4	-0.03	ns	
I practice good [study] skills...	1.3	-0.07	ns	
...best methodologies for reading...	0.97	0.53	0.02	0.30
...I have clear academic goals.	1.3	0.00	ns	
I effectively manage...my personal life...	0.83	-0.33	ns	
I am highly motivated...in my chosen major...	1.1	-0.23	ns	
...feel part of an academic learning community.	1.3	0.23	ns	
I am aware of...campus resources...	1.1	0.60	0.003	0.37
I feel good about myself...	0.83	-0.20	ns	
I feel good about the University...	1.3	-0.27	ns	

During the Fall 2020 semester, five items resulted in a significant difference between the beginning and end of the semester. This difference indicated a positive increase in self-perception in all five cases:

1. *I interact regularly with my professors in positive, beneficial ways, both in and out of the classroom.*
2. *I make effective use of my peers by regularly engaging in group study and collaborative learning.*

We note with particular interest that this item, while rated lower than in Fall 2020, increased significantly by the end of the semester by over twice as much as in Fall 2019.

3. *I am aware of the importance of being immersed in the academic environment of the institution and spend as much time on campus as possible. (expected based on the Fall 2020 situation)*
4. *I am aware of the best methodologies for reading for comprehension and practice these methodologies during my learning process.*

This item was also significantly different pre-post during the Fall 2019 semester.

5. *At the University of Rochester, I know other students in my classes, and feel part of an academic learning community. (noted above as unexpected based on the Fall 2020 situation)*

In comparison, there were only two significantly different items during the Fall 2019 semester:

1. *I am aware of the best methodologies for reading for comprehension and practice these methodologies during my learning process.*

This item was also significantly different pre-post during the Fall 2020 semester.

2. *I am aware of and make optimal use of campus resources such as the writing center, counseling center, student health center, library, and career center.*

We note with particular interest that this item was rated much lower during the Fall 2020 semester, which is expected based on the overall pandemic situation, but very concerning considering students' overall mental health declining and perceived academic workload increasing based on other research.

The same number of items were rated higher on average between the two semesters (8 items in both Fall 2020 and Fall 2019); however, 12 out of the 16 pre-post differences were higher in Fall 2020. This difference in outcomes across the two semesters indicates that even when the post-course ratings were lower for students during the Fall 2020 semester, they saw higher pre-post gains in their self-perceived academic success skills. In particular, the high levels of attribution of these gains to their experience in CHE 150 provides strong evidence that CHE 150 may have served as a cornerstone to students' coping academically with the pandemic. In particular, students' gains in connection with their professors and peers indicate a positive start to their journeys as engineers at the University of Rochester, as CHE 150 is designed to be. Another notable result is that students' attitude toward the University of Rochester stayed relatively consistent pre-post within semesters and across the two semesters. Students in CHE 150 seem to perceive the University of Rochester positively after the Fall 2020 semester, and their experience in this course may have mitigated the

negative effects of a particularly harrowing first-year first-semester experience.

D. Instructor Reflections on Student Outcomes

From the workshop instructor's perspective knowing that many instructors were struggling to engage students in hybrid classrooms, enthusiasm for the workshops in general and the project specifically was remarkable—especially considering comments from many of the students that they had no initial interest in their assigned piece of equipment during the unit operations exercise. However, once students began their research and found how ubiquitous their unit operation was in manufacturing common household products, they were fascinated. The level of detail in their discussion board posts indicated students were not only interested in their own unit operations, but also in those of their peers. Their feedback to one another was encouraging and constructive. Further, some students shared that the exercise helped cement their commitment to the major because they could clearly see what chemical engineers actually do and what their future career paths could entail.

The students' insights into societal inequalities connected to chemical engineering as a discipline were profound and poignant; the online format seemed to enable students to initiate conversations that they might not have felt comfortable initiating in-person, ultimately leading them to reach out to one another more easily later in the course for help or support from their peers. Anecdotally, students reported forming study groups with one another outside of the course after getting to know one another through the breakout discussions just as they would have during in-person instruction, and they found the smaller breakout discussions preferable to whole class discussions because of the ability to engage more directly with their peers. Overall, students seemed to view the workshops as a learning community and were committed to participating and connecting with one another to the best of their ability given the format and circumstances of the pandemic.

V. CONCLUSION

Based on our results, we conclude with brief summaries of how we see our research questions being addressed and our overall takeaways from the study.

A. How do workshops targeting critical academic success skills for engineers affect students' perceptions of those skills across in-person and hybrid formats?

Fall 2020 students (hybrid format) started lower and ended higher in their self-perceived academic success skills overall than Fall 2019 students (in-person format). Further, Fall 2020 students attributed more of the changes in their responses pre-post-course to their experience in CHE 150 than students in Fall 2019. Taken together, these results suggest that Fall 2020 students experienced the CHE 150 workshops as more important and impactful to their academic success compared to Fall 2019 students.

B. What academic success skills were well-targeted by the in-person and hybrid offerings of the course?

Four out of the five significant gains perceived by Fall 2020 students were related to concepts of connection and community

(social connections with their 1) professors and 2) peers, 3) awareness of the importance of being immersed in the college experience, and 4) feeling like a part of a community of learners), which indicates that the social and camaraderie-building aspects of the experience in CHE 150 workshops as well-targeted by the Fall 2020 implementation. The Fall 2019 implementation, on the other hand, was well-targeted to improving students' perceived awareness of on-campus resources. Both implementations improved students' perceived reading comprehension skills.

C. *How do the offerings differ in addressing the academic success skills based on students' perceptions?*

Based on Fall 2020 students' perceptions, during a semester in which students' mental health was poor, CHE 150 workshops were attributed as improving 14 out of the 16 academic success skills and significantly improved perceptions of four different skills related to social connection and a sense of community. However, one of the two less attributed skills in Fall 2020 was one of the significant gains in Fall 2019: awareness of on-campus resources. Based on these results, while students felt less familiar with campus in Fall 2020, they gained a strong awareness of the importance of being a part of the overall campus community and still found ways to connect with their peers and professors. Relatedly, the online discussion board introduced during the Fall 2020 implementation may have promoted students' reading comprehension skills while simultaneously providing a sense of connection with their peers. Because students were required to post and respond to posts, they were more likely to actually read one another's posts. Further, the students who were able to express their insights adeptly on the discussion board served as models for those who were less familiar with the process of reflection, and the post/respond format of assignments created repetition and practice with the workshop content. This iterative skill-building process may have improved students' recollections of positive interactions with classmates around the shared struggles of the Fall 2020 semester.

In conclusion, despite the stress and mental health decline observed in students during the Fall 2020 semester, our results indicate that CHE 150 improved students' self-perceptions during a challenging semester. Using the focuses of Landis' text to design academic success workshops and modifying those workshops to accommodate a hybrid learning environment allowed students to leave the course with a strong sense of community with one another as well as a positive perception of

the University of Rochester as a whole. We feel comfortable recommending a similar implementation for other first-year engineering courses operating in a hybrid format in the future.

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