From Assessment to Research: Evolution of the Study of a Two-Day Intervention for ChemE Sophomores

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Abstract

This paper describes the evolution of our assessment of a two-day workshop for rising chemical engineering (ChemE) sophomores into a more rigorous evaluation of the mechanisms behind its impact. In 2016, we implemented a voluntary two-day workshop (the "ChemE Camp") for rising chemical engineering sophomore students to try to improve their retention in our program. To assess the impact of the camp, we developed and administered surveys to camp attendees before the camp and to all ChemE students at the beginning and toward the end of the sophomore year. Student feedback about the camp was overwhelmingly positive, and the survey results indicated that students who attended the camp entered the sophomore year feeling more prepared for the curriculum and more comfortable with the ChemE major than those who did not. Camp attendees also reported a larger network of potential study partners than non-attendees and performed better in the Material and Energy Balances (MEB) course. To explain these observed effects, we enlisted the help of an engineering education researcher. After review of the relevant literature in learning theories, we decided to focus on the constructs of self-efficacy and social support. We then improved the design and rigor of our study and refined our surveys by introducing subscales from validated instruments of self-efficacy and social integration. Preliminary results suggest that the camp is having a positive effect on the self-efficacy, social and academic integration, and intent to persist of the students who attend, and data collection is ongoing to determine whether these effects are lasting. Here we describe our journey from the original development of the camp and assessment tools to our current research examining the factors that affect the achievement and persistence of ChemE sophomore students.

Introduction

Chemical engineering programs often experience significant attrition in student enrollment during the sophomore year, when students typically first encounter the MEB course [1,2]. The MEB course often involves a significant increase in rigor relative to typical first-year courses and is taken at a time when social support for the students is weakest because they are just being introduced to their chemical engineering classmates and faculty. Performance in such barrier courses often determines whether a student persists in engineering [3,4].

In conversations with chemical engineering faculty at other institutions, we learned about student-led retreats/camps being held for upcoming chemical engineering sophomore students at other universities just prior to the start of fall classes [5,6]. Students attending these camps interact with other ChemE students (both peers and upper-level students) and meet ChemE faculty and recruiters from industry. Organizers for one such camp summarize the intended benefit of attendance as follows: "The relationships formed during the camp aim to give sophomore students a supportive network of classmates, student mentors, faculty members, and industry professionals in order to promote retention and student success in the chemical engineering curriculum."[6]

We were persuaded by the potential benefits of such a program and eager to implement one at our own institution, so in 2016 we adapted ideas from these other camps to develop a voluntary two-day workshop (the "ChemE Camp") for rising sophomores. The camp is advertised to students who registered for the fall offering of the MEB course at a minimal cost to the student (~$25). The camp was designed to occur after campus move-in, but just before the start of fall classes. The workshop includes team-building exercises, hands-on projects, a lab tour, presentations from faculty and upper-level students about upcoming classes, the curriculum, and internship opportunities, as well as social activities. More details about the camp can be found in a previously published article [7]. A full list of activities (all of which took place on campus) are presented in Table 1, and some images from the camp appear in Figure 1. This camp is run at minimal cost, since reservations of classrooms and the recreation center, access to the challenge course, and participation from Career Center staff are free to faculty at our institution. Camp attendees receive an AIChE T-shirt, one year's membership in the local AIChE student chapter, and lunch and snacks both days. These costs, as well as those of miscellaneous supplies, are largely covered by the student fee, with overages subsidized by the AIChE student chapter.

Table 1. List of activities for the ChemE camp

Day 1	Day 2
• welcome/overview • icebreaker activities • AIChE overview • student presentations on co-op/internship/REU experiences • ChemE curriculum overview • ChemE faculty introduction • lunch • internship search strategies & interview tips • team-building exercises • student/faculty recreation and games	• more icebreakers • time management & study skills • advising topics • Q&A session with ChemE student panel • hands-on heat transfer project • lunch • industry presentations • mock interviews • ChemE lab tour • student/faculty recreation and games

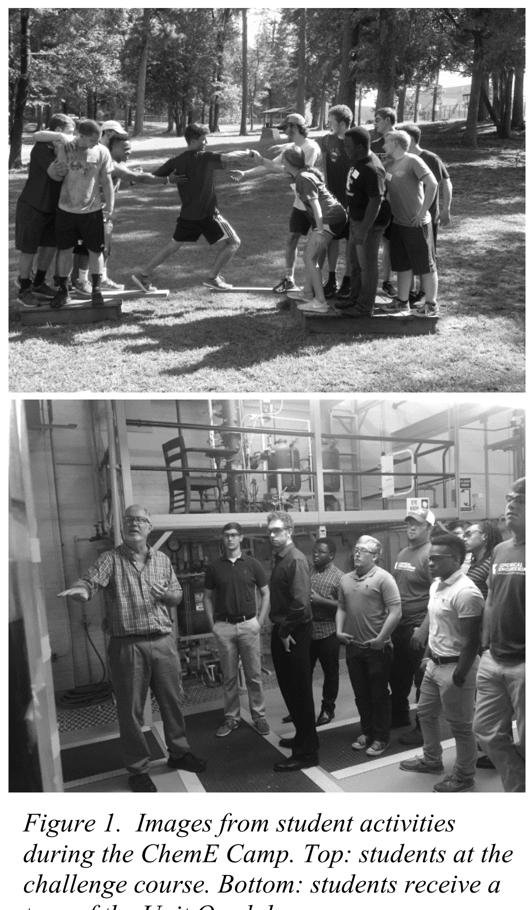

Figure 1. Images from student activities during the ChemE Camp. Top: students at the challenge course. Bottom: students receive a tour of the Unit Ops lab

Initial Assessment

While the camps being offered at other institutions provided critical inspiration for the development of our own camp, as well as ideas for many of our camp activities, they were not focused on assessment and therefore provided very little data intended to measure the effects of the camp. We set out to design a study aimed at quantitatively determining the impact of camp attendance. To this end, we developed our own survey instrument (see Appendix A) and received approval from the Institutional Review Board on campus to administer the survey to students.

These surveys contained a series of Likert response questions, which were converted to numerical values on a 5-point scale, ranging from 0 (Strongly Disagree) to 4 (Strongly Agree).

The responses to the three questions assessing student expectations of, knowledge of, and comfort with the ChemE curriculum were combined into a composite “curriculum preparedness” outcome, and the responses to the four questions assessing student comfort in the ChemE major were combined into a composite “comfort in ChemE major” outcome. The surveys also contained questions requesting numeric responses to the number of classmates and upper-level students that a student could potentially study with. Also included in the surveys were free-response questions used to determine students' motivations for attending the camp and to solicit formative feedback for improvement of the camp.

These surveys were completed anonymously and were administered to camp attendees at the start of camp ("Pre-Camp") and to all ChemE sophomores at the beginning of the fall MEB course ("Pre-Sophomore") and toward the end of the sophomore year ("Post-Sophomore"). Although anonymous, the Pre-Sophomore and Post-Sophomore surveys did include a question asking if the student had attended the camp. The immediate effects of the ChemE Camp were assessed using Student’s t-test to determine whether there was a difference in the average composite outcome ratings and number of potential study partners among campers from just before the camp (Pre-Camp) to just before the MEB course (Pre-Sophomore), a period of 3 days. To test whether any immediate ChemE Camp intervention effects were just “camp euphoria” or had a lasting effect, the Pre-Sophomore survey results were compared to the Post-Sophomore results using Student’s t-test. Any such changes were compared to the average changes observed from the non-camp cohort from Pre-Sophomore to Post-Sophomore to account for activities common to both cohorts during the sophomore year. P-values <0.05 were considered statistically significant.

Initial Results

A total of 35 students attended the camp during the first three offerings (Fall 2016 – Fall 2018) compared to 132 non-camper students. The campers' average composite rating of "curriculum preparedness" topics increased from 2.61 to 3.24 ($p<0.01$) from Pre-Camp to Pre-Sophomore (Figure 2a). The initial average composite rating for campers (Pre-Camp) was 0.34 points lower than the initial rating of the non-campers (Pre-Sophomore), but the improvement over the camp resulted in campers entering the sophomore year with a 0.29 point higher composite rating than non-campers on average. Over the course of the sophomore year, campers showed a small, non-significant decrease in the average rating of "curriculum preparedness" of 0.09 points ($p=0.36$) while the average rating from non-campers remained essentially constant (0.03 point increase, $p=0.74$).

Figure 2b shows that with topics related to "comfort in the ChemE major", camp attendees entered the camp (Pre-Camp) with approximately the same average rating that non-campers entered the sophomore year (Pre-Sophomore). However, from Pre-Camp to Pre-Sophomore, the rating of campers increased by 0.31 points ($p=0.02$), so campers entered the sophomore year with a 0.34 point higher composite rating than non-campers on average. Over the course of the sophomore year, both the campers and non-campers showed a similar small, non-significant decrease in the average rating (0.09 point decrease, $p=0.47$ for campers and 0.12 point decrease ($p=0.27$ for non-campers).

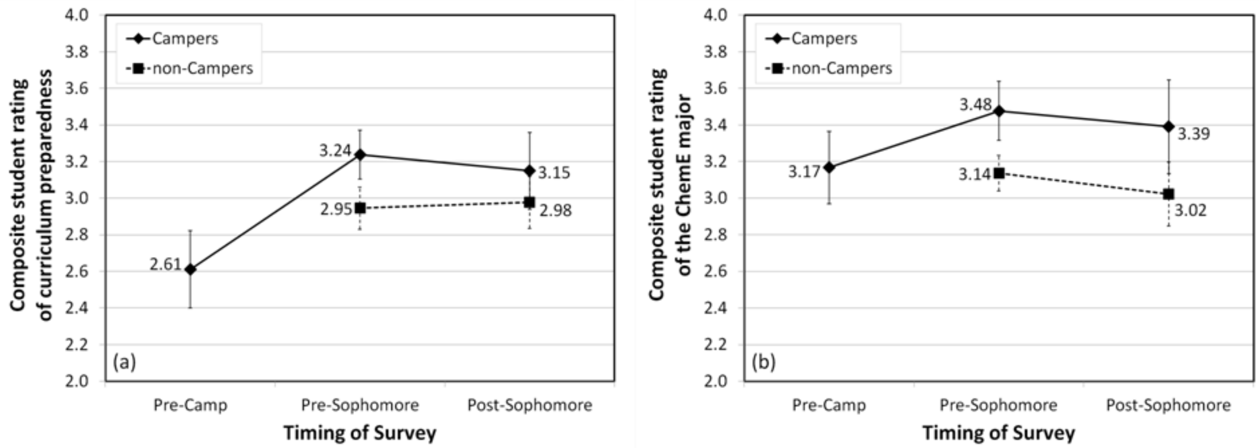

Figure 2. Average student survey ratings of (a) "curriculum preparedness" and (b) "comfort in ChemE major". Error bars indicate the 95% confidence interval. Data shown is for the first 3 full academic years of camp (Fall 2016-Spring 2019). Pre-Camp and Pre-Sophomore data for Fall 2019 shows a similar trend but are not included in Figure 2 because Post-Sophomore data is not yet available for these students.

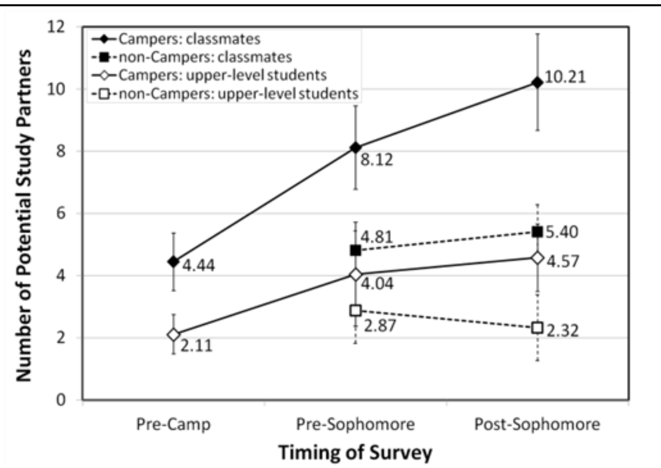

Figure 3. Average self-reported number of other students that campers/non-campers know and could study with. Error bars indicate the 95% confidence interval.

Our initial results also show a dramatic increase in the number of potential study partners for campers vs. non-campers. As shown in Figure 3, from Pre-Camp to Pre-Sophomore, campers reported an increase in the average number of chemical engineering classmates they know and could study with (from 4.44 to 8.12, $p<0.01$). This increase resulted in campers knowing an average of 3.31 more classmates at the start of the sophomore year than non-campers (8.12 vs. 4.81) even though, at the start of the camp, campers knew 0.37 fewer classmates than non-campers (4.44 vs. 4.81). Campers also reported an increase in the number of upper-level students they know (from 2.11 to 4.04, $p=0.05$). Thus, the camp served as a networking opportunity for the students and allowed them to have a greater pool of potential study partners upon the start of their sophomore classes. Additionally, campers met more classmates during the year than non-campers (average increase of 2.09 vs. 0.59) and maintained connections with upper-level students better than non-campers (average increase of 0.53 vs. decrease of 0.55).

Table 2 compares the performance of campers and non-campers in the four fall MEB course offerings during 2016 - 2019. Camp attendees performed better in the MEB course, earning a higher final grade and having a lower D/F/W rate. However, it is difficult to draw conclusions from these results, because the campers had a higher GPA upon entering the course (3.60 vs. 3.22). Since self-motivated learning has been correlated to greater academic achievement, there may be selection bias for students interested in the camp [8,9]. Future work will control for incoming GPA in assessing the impact of the camp.

Table 2. Student performance in MEB course, Fall 2016-2019

	Campers	Non-campers
Number of students	47	152
Overall GPA Pre-Sophomore	3.60	3.22
GPA in MEB course	2.38	1.93
% D/F/W in MEB course	48.9	63.8

Study Improvement

The surveys administered in previous years of the camp have limitations. For starters, the fact that students completed them anonymously restricted analysis to tracking the trends of each cohort (camper and non-camper) in aggregate over time and comparing the aggregate responses. Having a third party administer the surveys while keeping a cipher to match each student to his/her survey responses will enable deeper analysis. Responses of individual students can be tracked throughout the year and connected back to student grades while keeping the response data de-identified from the researchers, who are also instructors.

Secondly, the questions asked on the initial surveys focus on the achievement of narrow aspects of the camp's goals, rather than validated constructs in learning or motivation theory, so it is difficult to identify the mechanisms at work to explain the positive effects of the camp. Additionally, any interpretation of the results is further complicated by the potential selection bias associated with camp attendance. We have already seen that camp attendees enter the sophomore year with a higher college GPA than non-attendees, which could indicate a higher level of general ability or achievement, making it problematic to attribute their better performance in the MEB course to camp attendance.

In 2018, we reached out to an engineering education researcher to help us design a more rigorous study of the mechanisms at play so that we could identify more generalizable knowledge. Together we decided to apply the Social Cognitive Career Theory (SCCT) framework – which was developed to explain how vocational/academic interests are developed, choices made, and performance attained – to model the effects of self-efficacy and social support on the persistence and achievement in chemical engineering. Research has shown a correlation between student self-efficacy and academic performance and achievement [10-14]. Additionally, studies suggest that development of social networks with peers can lead to greater engagement in learning [15-17] and that the quality of interactions between teachers and students both inside and outside the classroom has a significant impact on student experience and student success [18,19]. However, many of these studies in STEM curricula have focused on first-year students [20-23], and it is less well-known to what extent the factors that affect performance and achievement in first-year courses remain salient into the sophomore year. The SCCT framework is ideal for our purposes because it has been extensively applied in the academic setting with much of the research focusing on the relationship between self-efficacy and the outcomes of academic performance and persistence [24].

We have refined the survey instrument to include specific questions assessing student self-efficacy, intent to persist, and social support to allow the relationships between these variables to be explored (see Appendix B). Chemical engineering self-efficacy is assessed using the General Engineering Self-Efficacy subscale [25] with items modified by replacing "engineering" with "chemical engineering". Students are asked to indicate their level of certainty (on a 6-point Likert-type scale, ranging from 1, "completely uncertain", to 6, "completely certain") in statements like "I can master the content in the chemical engineering-related courses I am taking this quarter", "I can do a good job on almost all my chemical engineering coursework if I do not give up", etc. Coping self-efficacy is assessed using the Longitudinal Assessment of Engineering Self-Efficacy [26] coping self-efficacy subscale modified by Concannon and Barrow [27]. As a means of assessing social supports, we used the Social Integration and Academic Integration subscales of the Engineering Student Integration Instrument [28], modified by replacing "engineering" with "chemical engineering". Students are instructed to use a 7-point scale with anchored ends (Strongly Disagree to Strongly Agree) to indicate their level of agreement with statements such as "I can effectively work in study groups with other chemical engineering students", "I have sufficient access to chemical engineering faculty/staff", etc. A short-term proxy for persistence, intent to persist, is be modeled after work by Lent and colleagues with survey items asking students to indicate their level of agreement (on a 5-point scale) with statements about their academic intentions such as "I intend to remain enrolled in my engineering major over the next quarter", "I am considering changing majors", etc. [13].

In addition to modifying the surveys to include validated subscales to measure theoretical constructs, we also improved the structure of the survey instrument itself. For example, we moved demographic questions from the beginning of the survey to the end. Asking students to identify their gender, race, etc. at the beginning of the survey risks activating stereotypes in the minds of the students and potentially biasing the results, a phenomenon known as "priming", which is related to stereotype threat [29]. Also, historical terminology with potential gender bias was changed to more gender-neutral language (such as "upperclassmen" to "upper-level students"). The reporting of race and ethnicity was changed from a fill-in-the-blank response to a check-the-appropriate-box(es) response with standardized categories consistent with government reporting.

Recent Results

The 2018 survey was modified to include the section on intent to persist. A total of 15 students attended the camp compared to 33 non-campers in the Fall 2018 MEB class. The results on intent to persist from the 2018-2019 academic year are shown in Figure 4. Campers improved by 0.32 points from 5.98 to 6.30 (p=0.17) on this scale. The survey results show that campers gave a lower intent to persist (and average rating to the initial survey questions related to the ChemE curriculum) prior to the start of the

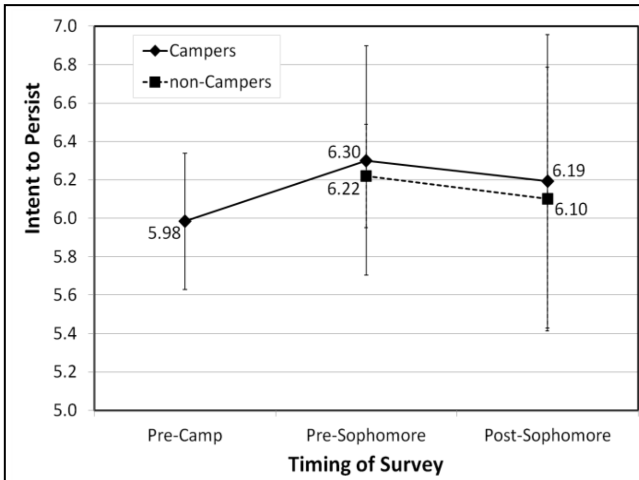

Figure 4. Average student survey ratings of intent to persist. Error bars indicate the 95% confidence interval.

camp than non-campers did at the beginning of the sophomore year. Both campers and non-campers exhibited a slight decline in this rating over the course of the sophomore year.

In 2019, we incorporated the subscales assessing chemical engineering self-efficacy, coping self-efficacy, and social and academic integration into our surveys. A total of 12 students attended the Fall 2019 camp compared to 20 non-camper students that were taking the MEB course for the first time in Fall 2019. The results are shown in Figure 5. The data all show an improvement of the campers' rating from Pre-Camp to Pre-Sophomore with the effect especially pronounced for the coping self-efficacy (0.50 point increase, p=0.04, see Figure 5b) and social integration and academic integration (0.65 point increase, p=0.01, see Figure 5c). These ratings show similar trends to what is seen in Figures 1 and 2: campers begin with ratings comparable to or even less than those of non-campers, but experience a dramatic improvement from Pre-Camp to Pre-Sophomore and enter their sophomore year with higher ratings than non-campers. The qualitative similarity between Figure 5c and Figure 3 is logical since the reported number of potential study partners is a single-item measure of social integration. The administration of surveys in Spring 2020 will help determine whether these rating increases experienced by campers are sustained throughout the sophomore year. The data in Figures 2-4 suggest that there is some lasting effect.

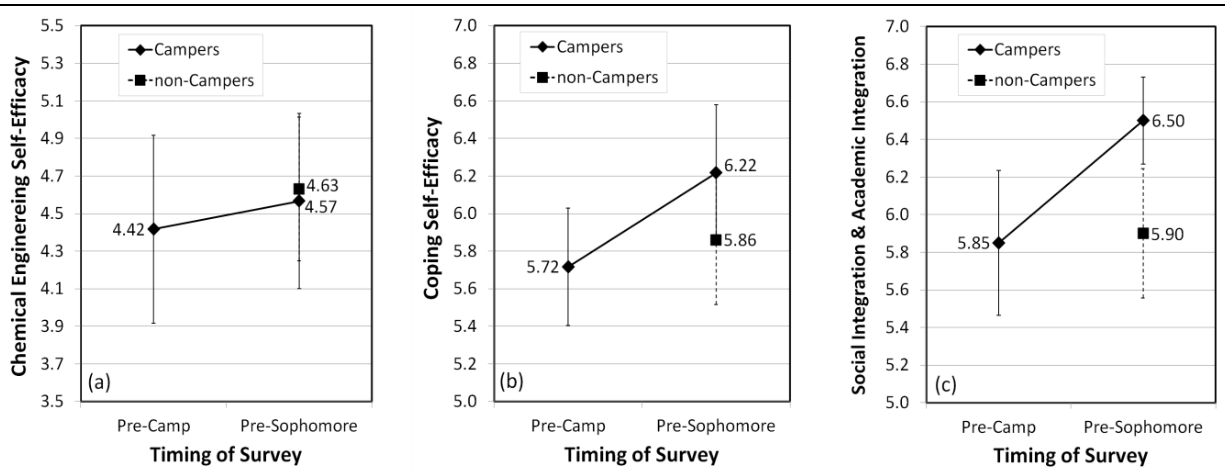

Figure 5. Average student survey ratings of (a) chemical engineering self-efficacy, (b) coping self-efficacy, and (c)social integration and academic integration. Error bars indicate the 95% confidence interval.

Future Work

We will continue to collect student data using the improved surveys with responses tracked to individual students. Once the data set is large enough, we will employ structural equation modeling to test the relationships between the factors of self-efficacy and social support and the outcomes of academic performance and persistence. Regression analysis will be performed to adjust for factors such as incoming GPA. Additionally, we will conduct thematic analysis on the open-ended survey responses to identify common concerns about the sophomore year and reasons for choosing chemical engineering. This information, along with specific camp feedback, can be used to improve the camp and/or the sophomore experience.

Conclusions

Our study has evolved from the implementation of the ChemE Camp and simple assessment of its objectives to a more rigorous evaluation of the mechanisms behind its impact. Our initial data indicated that the ChemE Camp is having a positive effect on its attendees. After improving our survey instrument so that it is based on fundamental concepts in SCCT and makes use of previously-validated subscales, the preliminary data suggest that the camp is improving the self-efficacy, social and academic integration, and intent to persist of those that attend. Although focused on chemical engineering students, the design of the study and intervention make the methods and findings broadly applicable.

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Appendix A. Initial survey used for ChemE Camp assessment.

Age: ____
Race/Ethnicity: ________________________________
Gender: ______________________________________
I participated in the ChemE Camp: YES / NO

	Strongly Agree	**Agree**	**Neutral**	**Disagree**	**Strongly Disagree**
L1: I feel comfortable going into my courses this year.					
L2: I know what to expect in the curriculum this year.					
L3: I know what to expect in the curriculum until graduation.					
L4: I am confident in my selection of ChemE as a major.					
L5: I feel comfortable interacting with faculty.					
L6: I am familiar with internship and co-op opportunities available to me.					
L7: I am familiar with the fall Career Fair					
L8: I know how to write an effective resume.					
L9: I feel confident in my interview skills.					
L10: I am satisfied with the ChemE curriculum so far.					

	Free response questions
My biggest factor in choosing in choosing/keeping the ChemE major is/was…	
My biggest concern about the sophomore year is/was…	
The number of my ChemE classmates who I know and could study with is ...	
The number of ChemE upperclassmen who I know and could study with is…	

If you are about to attend the ChemE Camp, what are you looking to get out of the camp?	

Appendix B. Current survey used in the SCCT-framed research study.

Chemical Engineering Sophomore Survey 2019 (Pre-Soph)

We invite you to participate in this survey to help us understand the experience of chemical engineering sophomores. Participation in the study is voluntary. You may refuse to answer any question or withdraw from the study at any time without penalty (e.g., leave questions blank that you do not want to answer).

Below are statements about studying chemical engineering. To the right of each statement rate your level of certainty that you can perform this task/activity, using a 6-point scale ranging from 1 (completely uncertain) to 6 (completely certain).

Mark only one oval per row.	1 completely uncertain	2	3	4	5	6 completely certain
1. I can master the content in the chemical engineering-related courses I am taking this quarter.	⬭	⬭	⬭	⬭	⬭	⬭
2. I can master the content in even the most challenging chemical engineering course if I try.	⬭	⬭	⬭	⬭	⬭	⬭
3. I can do a good job on almost all my chemical engineering coursework if I do not give up.	⬭	⬭	⬭	⬭	⬭	⬭
4. I can learn the content taught in my chemical engineering-related courses.	⬭	⬭	⬭	⬭	⬭	⬭
5. I can earn a good grade in my chemical engineering-related courses.	⬭	⬭	⬭	⬭	⬭	⬭

For each statement below indicate whether you Strongly Disagree, Disagree, Slightly Disagree, Neither Disagree nor Agree, Slightly Agree, Agree, or Strongly Agree by filling in the appropriate oval.

To what extent do you AGREE?
1 = Strongly Disagree 2 = Disagree 3 = Slightly Disagree 4 = Neither disagree nor agree
5 = Slightly Agree 6 = Agree 7 = Strongly Agree

I am confident that ...	1 strongly disagree	2	3	4	5	6	7 strongly agree
6. I can cope with not doing well on a test.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
7. I can make friends with people from different backgrounds and/or values.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
8. I can cope with friends' disapproval of the chemical engineering major.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
9. I can approach a faculty or staff member to get assistance.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
10. I can adjust to a new campus environment.	⬭	⬭	⬭	⬭	⬭	⬭	⬭

We are interested in your opinion on these items related to your experience as a chemical engineering student. There are no right or wrong answers.

To what extent do you agree or disagree with the following statements?

1 = Strongly Disagree 2 = Disagree 3 = Slightly Disagree 4 = Neither disagree nor agree
5 = Slightly Agree 6 = Agree 7 = Strongly Agree

	1 strongly disagree	2	3	4	5	6	7 strongly agree
11. My interactions with chemical engineering faculty are generally positive.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
12. I can effectively communicate with chemical engineering faculty and staff.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
13. I have sufficient access to resources that can help me succeed academically.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
14. I have sufficient access to chemical engineering faculty/staff.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
15. Overall, the chemical engineering program supports me academically.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
16. I can collaborate with other chemical engineering students academically.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
17. I can positively interact with other chemical engineering students.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
18. I am comfortable networking with other chemical engineering students.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
19. I can effectively work in study groups with other chemical engineering students.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
20. I can effectively work on teams with other chemical engineering students.	⬭	⬭	⬭	⬭	⬭	⬭	⬭

Please indicate how true each statement is for you:

Mark only one oval per row.	1 not at all	2	3	4 somewhat	5	6	7 very true
21. I intend to stick with my chemical engineering major, no matter what.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
22. I intend to remain enrolled in chemical engineering over the next quarter.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
23. I am not sure if I will complete my degree in chemical engineering.	⬭	⬭	⬭	⬭	⬭	⬭	⬭
24. I am considering changing to a different major.	⬭	⬭	⬭	⬭	⬭	⬭	⬭

To what extent do you agree or disagree with the following statements?

Mark only one oval per row.	1 strongly disagree	2 disagree	3 neutral	4 agree	5 strongly agree
25. I feel comfortable going into my courses this year.	⬭	⬭	⬭	⬭	⬭
26. I know what to expect in the curriculum this year.	⬭	⬭	⬭	⬭	⬭
27. I know what to expect in the curriculum until graduation.	⬭	⬭	⬭	⬭	⬭
28. I am confident in my selection of chemical engineering as a major.	⬭	⬭	⬭	⬭	⬭
29. I feel comfortable interacting with faculty.	⬭	⬭	⬭	⬭	⬭
30. I am familiar with internship and co-op opportunities available to me.	⬭	⬭	⬭	⬭	⬭
31. I am familiar with the fall Career Fair.	⬭	⬭	⬭	⬭	⬭
32. I know how to write an effective resume.	⬭	⬭	⬭	⬭	⬭
33. I feel confident in my interview skills.	⬭	⬭	⬭	⬭	⬭
34. I am satisfied with the chemical engineering curriculum so far.	⬭	⬭	⬭	⬭	⬭

Free response questions

My biggest factor in choosing the chemical engineering major was...

My biggest concern about the sophomore year is...

The number of my chemical engineering classmates whom I know and could study with is ____________
(please report a number or numerical range)

The number of chemical engineering juniors and seniors whom I know and could study with is _________
(please report a number or numerical range)

I participated in the ChemE Camp held just before the start of fall classes (circle one):

not at all **1 day** **both days**

Why or Why not?

What aspect(s) of the camp did you find particularly beneficial?

What aspect(s) could be improved or what suggestions do you offer for improving the camp?

My current university GPA falls into this range (check one): ☐ **less than 2.5** ☐ **2.5-2.74** ☐ **2.75-2.99** ☐ **3.00-3.19** ☐ **3.20-3.39** ☐ **3.40-3.54** ☐ **3.55-3.69** ☐ **3.70-3.84** ☐ **3.85-4.0**

I have already secured an industrial internship or co-op for the coming summer (circle one): **Yes / No**

Chemical engineering has been my major since enrolling in college (circle one): **Yes / No**

If no: My first major was ___________________

This is my first attempt at the CMEN 202 course (circle one): **Yes / No**

Demographic information will be helpful in analyzing the survey results, but as a reminder you may leave questions blank that you do not want to answer.

Ethnicity: ☐ Hispanic or Latino ☐ Not Hispanic or Latino

Race (select all that apply):

☐ American Indian or Alaska Native

☐ Asian

☐ Black or African American

☐ Native Hawaiian or Other Pacific Islander

☐ White

Gender: ☐ Female ☐ Male ☐ Prefer to Self-Describe: ______________________

Thank you for your participation in this survey. Your feedback is appreciated.