

Work in Progress: Identifying Success Factors for Chemical Engineering Sophomores and Testing the Effects of an Intervention

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Abstract

Our study aims to examine factors that influence the academic achievement and persistence of chemical engineering students in the understudied sophomore year, where many programs observe significant attrition. Specifically, we focus on the constructs of self-efficacy and social support. Research has indicated that these factors can have a significant impact on student experience and student success. We generated surveys which include subscales from validated instruments used in the study of self-efficacy and social integration and administered these surveys to chemical engineering (“ChemE”) students at the beginning and end of the sophomore year. Social Cognitive Career Theory was used to hypothesize the expected (positive) relationships between the factors of self-efficacy and social support and the outcomes of student achievement and persistence. When the data set is large enough, path analysis will be used to test these hypotheses, adjusting for prior achievement using indicators such as first-year GPA. Achievement is measured in the short term by performance in sophomore-level ChemE courses and in the long term by final ChemE GPA. Persistence is measured in the short term by responses to survey questions assessing intent to persist and in the long term by graduation rate.

Additionally, we will test whether participation in a two-day voluntary workshop (the “ChemE Camp”) held just before the start of fall classes has a lasting impact on the factors of self-efficacy and social support. The same surveys described above are administered to camp attendees before and after the camp, and preliminary results show an increase in self-efficacy, social and academic integration, and intent to persist for those who attend. These effects appear to largely sustain throughout the sophomore year, in contrast to the results observed for non-attendees. In this work-in-progress, we share our findings from the most recent academic year illustrating the positive effects of the two-day intervention on self-efficacy and social support.

Introduction

The transition from the first year to the sophomore year can be challenging for new chemical engineering students. The Material and Energy Balances (MEB) course at many universities is first offered to students in the fall of their sophomore year. The MEB course often involves a significant increase in rigor relative to typical first-year courses, but the course is taken when social support for the students is weakest because they are just being introduced to their chemical engineering classmates and faculty.

Significant attrition from chemical engineering programs is a well-documented phenomenon [1,2], and much of it occurs when students encounter the MEB course. Performance in such barrier courses often determines whether a student persists in engineering [3,4]. Performance in the MEB course at our institution has been tracked for several years. It has been observed that a large percentage of students earn a grade of D, F, or W (Withdrawal) in the course (53.7% over the past 10 fall offerings).

Research has shown a correlation between student self-efficacy and academic performance and achievement [5-9]. Additionally, studies suggest that development of social networks with peers can lead to greater engagement in learning [10-12] 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 [13,14]. However, many of these studies in STEM curricula have focused on first-year students [15-18], and it is less well-known to what extent factors that affect performance and achievement in first-year courses remain salient into the sophomore year.

In this work, we aim to explore the impacts of self-efficacy and social support on sophomore chemical engineering students since the sophomore year is often when students begin to take major-specific courses. Additionally, we propose to study whether participation in a voluntary two-day workshop has lasting effects on students' self-efficacy and social support. Although focused on chemical engineering students, the design of the study and workshop make the methods and findings broadly applicable.

Intervention

Since 2016, we have offered a voluntary two-day workshop ("ChemE Camp") at our institution for rising chemical engineering sophomore students just before the start of classes in the fall. The workshop includes team-building exercises, a hands-on project, career fair information, a lab tour, presentations from faculty and upper-level students about upcoming classes, the curriculum, and internship opportunities, and some recreational games. A detailed description of the camp and its activities can be found elsewhere [19,20]. In addition to being a venue for students to learn more about chemical engineering courses and the profession, it also serves as an opportunity for them to meet peers and interact with upper-level students and faculty. The informal faculty-student interaction fostered by the workshop has the potential to increase the students' comfort level with the faculty, which has been shown to be an important factor in student success [13,21-23].

Methods

Data Collection

Surveys are administered to all chemical engineering sophomores in the fall before the first MEB class ("Pre-Soph") and in the spring just before the withdrawal deadline (7 weeks into 10-week quarter) in the sophomore Fluids course ("Post-Soph"). These surveys include subscales from several published instruments, described below. The same surveys are also administered to students attending the ChemE Camp at the beginning and end of the camp ("Pre-Camp" and "Post-Camp," respectively). To focus on the sophomore experience, responses from students who were repeating the MEB course were excluded from the analysis.

The grades of students who have consented to the study are collected for the MEB course, the Fluids course, and subsequent chemical engineering courses via academic records. The percentage of sophomores who attempted the MEB course that earn the B.S. degree in chemical engineering within four years of the first attempt of the MEB course will also be monitored. The final GPA of graduating students in chemical engineering courses and this graduation rate will be used as additional metrics for achievement and persistence in longitudinal studies. In the short-term, our study will focus on academic performance in sophomore-level courses and the "intent to persist" (described below) as measures of achievement and persistence, respectively.

Measures (summarized in Table 1)

Prior Achievement – Prior achievement is operationalized using academic record data originating from three different sources: standardized test scores (ACT or SAT), high school GPA, and college GPA at the end of the first year.

Chemical Engineering Self-Efficacy - Chemical engineering self-efficacy is assessed using the General Engineering Self-Efficacy subscale developed by Mamaril et al. [24] with items modified by replacing “engineering” with “chemical engineering.” Students are asked to indicate their level of certainty in statements like “I can master the content in the chemical engineering-related courses I am taking this quarter.”

Coping Self-Efficacy - Coping self-efficacy is assessed using the Longitudinal Assessment of Engineering Self-Efficacy (LAESE) [25] coping self-efficacy subscale modified by Concannon and Barrow [26]. Students are asked to indicate their level of agreement with statements such as “I can cope with not doing well on a test.”

Proximal Contextual Influence (Social Support) - To assess social support, we use the Social Integration and Academic Integration subscales of the Engineering Student Integration Instrument (ESII) [27], modified by replacing “engineering” with “chemical engineering.” Students are instructed to indicate their level of agreement with statements such as “I can effectively work in study groups with other chemical engineering students.”

Performance - Short-term performance measures used for this study are the letter grade in the MEB course, the letter grade in the Fluids course, and second year GPA (the sophomore courses at our institution are fairly standardized for chemical engineering students).

Persistence - A short-term proxy for persistence, intent to persist, is modeled after work by Lent and colleagues with survey items asking students to indicate their level of agreement with statements about their academic intentions such as “I intend to remain enrolled in my engineering major over the next quarter” and “I am considering changing majors” [8].

Table 1. Variables and outcomes to be measured.

Factor	Outcome
Prior achievement • ACT/SAT score • High school GPA • First-year GPA	Performance • MEB letter grade • Fluids letter grade • Second year GPA • Final ChemE GPA
Self-efficacy • Chemical engineering self-efficacy • Coping self-efficacy	
Proximal contextual influences (social support) • Social Integration • Academic Integration	Persistence • Intent to Persist • Graduation rate within 4 years of 1st MEB attempt

In addition to the quantitative survey instruments described above, the surveys also include some free-response questions, such as “My biggest factor in choosing the chemical engineering major was ...”, “What are you looking to get out of the camp?” (Pre-Camp), “What aspect(s) of the camp did you find particularly beneficial?” (Post-Camp), “Did you participate in the ChemE Camp? Why or why not?” (Pre-Soph). While some of these responses are used for formative assessment and improvement of the camp itself, others can be used in a thematic analysis to help explain the quantitative results.

Analysis

To determine the relationship between the factors of self-efficacy and social support and the outcomes of academic achievement and persistence, path analysis will be employed.

Conventional path-analytic procedures will be followed and the significance of the regression coefficients from each factor (first-year GPA, ChemE self-efficacy, coping self-efficacy, social integration, and academic integration) to each outcome (MEB letter grade, Fluids letter grade, second-year GPA, and Intent to Persist) will be assessed. We hypothesize that the coefficients from each factor to each outcome will be positive and statistically significant. Ongoing data collection will allow for the effects of the factors on longer-term outcomes like final ChemE GPA and graduation rate to be determined. Once a sufficiently large data set is developed a full structural equation model could be employed, which will allow each survey-based factor to be modeled as a latent variable, accounting for measurement error.

To determine the influence of a two-day intervention on self-efficacy and social support, the survey responses of students attending the ChemE Camp at two time points will be directly compared using paired Student's t-tests and linear regression to adjust for factors such as gender, race, and GPA. The immediate effects of the ChemE Camp will be assessed by comparing survey results from just before the camp (Pre-Camp) and just before the MEB course (Pre-Soph), a period of 3 days. (Prior data shows no statistical difference between the Post-Camp and Pre-Soph survey responses of camp attendees.) Any changes in self-efficacy or social support ratings deemed statistically significant would suggest that the intervention had an impact on these outcomes.

To test whether any immediate ChemE Camp intervention effects were lasting, the Pre-Soph survey results will be compared to the Post-Soph results using paired Student's t-tests. Any such changes will be compared to the average changes observed from the non-camp attending cohort from Pre-Soph to Post-Soph to account for activities common to both cohorts during the sophomore year. For consistent analysis of the same cohorts over time, only campers that completed the Pre-Camp, Pre-Soph, and Post-Soph surveys will be included in the pair-wise comparisons. P-values <0.05 are considered statistically significant.

Preliminary results

Starting in Fall 2019, we incorporated the subscales assessing chemical engineering self-efficacy, coping self-efficacy, and social and academic integration into our surveys. The full survey instrument used can be found in a previous publication [20], with chemical engineering self-efficacy rated on a 6-point Likert scale [1 = completely uncertain, 6 = completely certain] and coping self-efficacy, social and academic integration, and intent to persist all rated on a 7-point Likert scale [1 = strongly disagree/not at all, 7 = strongly agree/very true]. A total of 12 students attended the Fall 2019 camp (average Pre-Soph GPA of 3.64, standard deviation of 0.36) compared to 20 non-camper students that were taking the MEB course for the first time in Fall 2019 (average Pre-Soph GPA of 3.44, standard deviation of 0.35). The coronavirus pandemic forced our Post-Soph surveys to be administered electronically, which hurt the response rate (9 camper and 10 non-camper responses). These 19 responses are the ones analyzed and presented below.

The self-efficacy results for the 2019-2020 academic year are shown in Figure 1. The data reflects an improvement of the campers' self-efficacy from Pre-Camp to Pre-Sophomore. The effect is pronounced, and statistically significant, for both chemical engineering self-efficacy

(0.36 point increase, $p=0.04$) and coping self-efficacy (0.44 point increase, $p=0.02$). Campers show an increase in both chemical engineering and coping self-efficacy rating from Pre-Soph to Post-Soph (0.22 point increase, $p=0.47$, and 0.15 point increase, $p=0.27$, respectively) while the non-campers exhibit a decrease in both (0.38 point decrease, $p=0.36$, and 0.39 point decrease, $p=0.17$, respectively), although these changes were not statistically significant. The unique conditions of the spring, with students at our institution leaving campus and course instruction rapidly shifting to remote/online delivery, could certainly affect student responses, but it is interesting to observe that the two cohorts appear to be impacted differently.

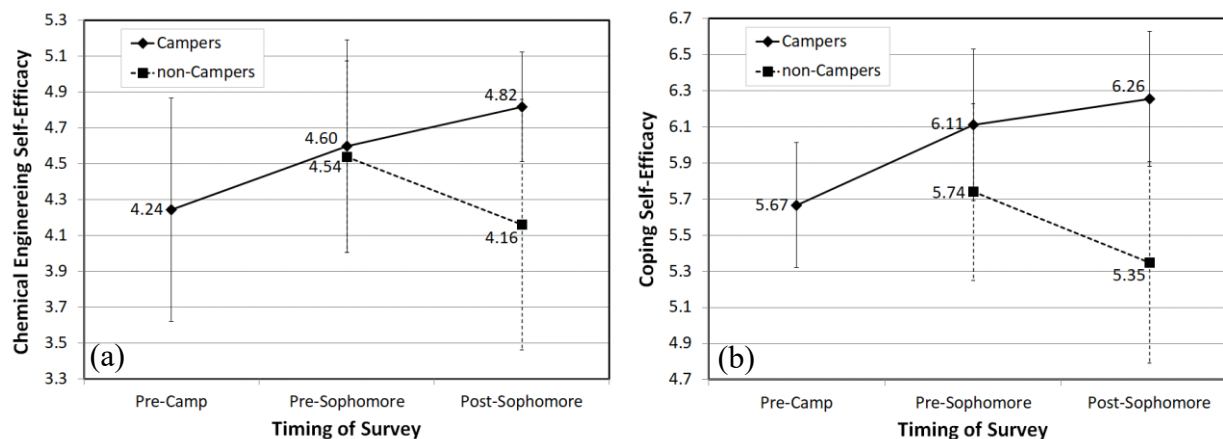


Figure 1. Average student survey ratings of (a) chemical engineering self-efficacy and (b) coping self-efficacy for the 2019-2020 academic year. Error bars indicate the 95% confidence interval.

Figure 2(a) shows the average student ratings of social integration and academic integration for the 2019-2020 academic year. Campers showed a marked, statistically significant, increase in this rating from Pre-Camp to Pre-Soph (0.71 point increase, $p=0.02$). Both cohorts' ratings hold steady throughout the sophomore year from Pre-Soph to Post-Soph. Figure 2(b) show the average student ratings of intent to persist for the 2019-2020 academic year. Campers essentially remained unchanged (0.02 point decrease, $p=0.90$) from Pre-Camp to Pre-Soph on this scale. Campers showed an increase in intent to persist from Pre-Soph to Post-Soph (0.53 point increase, $p=0.07$) while non-campers showed a decrease (0.40 point decrease, $p=0.35$) although neither change was statistically significant.

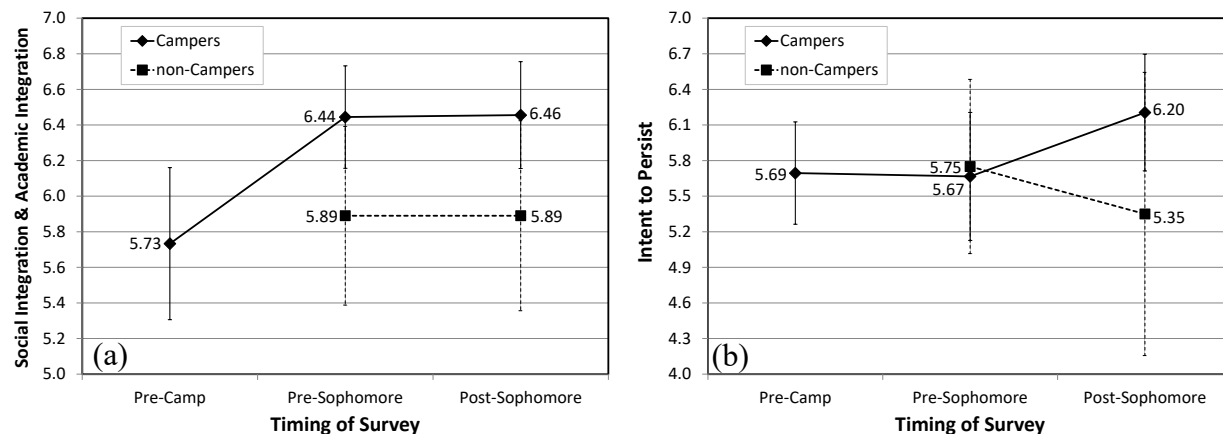


Figure 2. Average student survey ratings of (a) social integration and academic integration and (b) intent to persist for the 2019-2020 academic year. Error bars indicate the 95% confidence interval.

Some interesting observations can be made from the data shown in Figures 1 and 2. First, for the factors of chemical engineering self-efficacy, coping-self efficacy, and social and academic integration, the camper cohort entered the camp with a lower reported rating than that of non-campers entering the sophomore year and showed an increase in the rating from Pre-Camp to Pre-Soph. This boost in ratings allowed them to enter the sophomore year with ratings higher than those of the non-camper cohort. The intent to persist data exhibit different behavior: the camper cohort showed essentially no change from Pre-Camp to Pre-Soph and entered the sophomore year with a slightly lower rating than the non-camper cohort. Additionally, the self-efficacy and intent to persist data suggest that the camper cohort does a better job maintaining and improving upon the Pre-Soph factor ratings throughout the sophomore year to the Post-Soph assessment than the non-campers.

Future work

Because of our current limited sample size, we compared the pair-wise ratings of the two cohorts. As the data set grows over time, we will be able to power a path analysis to assess whether the factors of chemical engineering self-efficacy, coping self-efficacy, social integration, and academic integration have a significant impact on the achievement and persistence of chemical engineering sophomore students. Continued comparison of the Pre-Camp and Pre-Soph survey responses of camp-attending students will help determine whether the camp impacts these factors, and the ongoing comparison of the Pre-Soph and Post-Soph ratings of both cohorts will help establish whether any such changes in these factors are lasting. Additionally, a project evaluation team will conduct interviews with students from both cohorts to collect feedback regarding students' choice to attend the camp, concerns about the sophomore year, reasons for choosing the chemical engineering major, as well as specific feedback about the camp from those that attended. This information can be used to improve the camp and/or the sophomore experience.

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References

- [1] Culberson, O.L. "Attrition of ChE Undergrads," *Chemical Engineering Education*, **4**(1), 24-27 (1970)
- [2] Felder, R.M., Forrest, K.D., Baker-Ward, L., Dietz, E.J., and Mohr, P.H. "A Longitudinal Study of Engineering Student Performance and Retention. I. Success and Failure in the Introductory Course," *Journal of Engineering Education*, **82**(1), 15-21 (1993)
- [3] Suresh, R. "The Relationship Between Barrier Courses and Persistence in Engineering," *Journal of College Student Retention: Research, Theory, & Practice*, **8**(2), 215-239 (2006)

- [4] Gainen, J. "Barriers to Success in Quantitative Gatekeeper Courses," *New Directions for Teaching and Learning*, **61**, 5-14 (1995)
- [5] Pintrich, P and Schunk, D. "Motivation in Education: Theory, Research, and Applications," Prentice Hall, Englewood Cliffs, NJ (1996)
- [6] Pajares, F. "Self-Efficacy Beliefs in Academic Settings," *Review of Educational Research*, **66**(4), 543-578 (1996)
- [7] Hackett, G., Betz, N.E., Casas, J.M. and Rocha-Singh, I.A. "Gender, Ethnicity, and Social Cognitive Factors Predicting the Academic Achievement of Students in Engineering," *Journal of Counseling Psychology*, **39**(4), 527-538 (1992)
- [8] Lent, R.W., Brown, S.D., Schmidt, J., Brenner, B., Lyons, H. and Treistman, D. "Relation of Contextual Supports and Barriers to Choice Behavior in Engineering Majors: Test of Alternative Social Cognitive Models," *Journal of Counseling Psychology*, **50**(4), 458-465 (2003)
- [9] Seymour, E. and Hewitt, N.M. "Talking about Leaving: Why Undergraduates Leave the Sciences." Boulder, CO. Westview Press (1997)
- [10] Matthews, K.E., Andrews, V. and Adams, P. "Social Learning Spaces and Student Engagement," *Higher Education Research & Development*, **30**(2), 105-120 (2011)
- [11] Acker, S.R. and Miller, M.D. "Campus Learning Spaces: Investing in How Students Learn," *Educause Center for Applied Research Bulletin*, **2005**(8), 1-11 (2005)
- [12] Sen, A. and Passey, D. "Globalisation of Next Generation Technology Enhanced Learning Environment (TELE) for STEM Learning: Contextualizations in the Asia-Pacific Region," *2013 IEEE Fifth International Conference on Technology for Education (T4E)*, 111-118 (2013)
- [13] Boles, W. and Whelan, K., "Barriers to Student Success in Engineering Education," *European Journal of Engineering Education*, **42**(4), 368-381 (2017)
- [14] Seymour, E. and Hewitt, N.M., "Talking about Leaving: Factors Contributing to High Attrition Rates among Science, Mathematics, and Engineering Undergraduate Majors," Final report to the Alfred P. Sloan Foundation on an ethnographic inquiry at seven institutions. Boulder: University of Colorado Bureau of Sociological Research, 1994
- [15] Jones, B.D., Paretto, M.C., Hein, S.F., and Knott, T.W. "An Analysis of Motivation Constructs with First-Year Engineering Students: Relationships Among Expectancies, Values, Achievement, and Career Plans," *Journal of Engineering Education*, **99**(4), 319-336 (2010)
- [16] Lent, R.W., Sheu, H.B., Singley, D., Schmidt, J.A., Schmidt, L.C. and Gloster, C.S. "Longitudinal Relations of Self-Efficacy to Outcome Expectations, Interests, and Major Choice Goals in Engineering Students," *Journal of Vocational Behavior*, **73**(2), 328-335 (2008)
- [17] Van Soom, C. and Donche, V. "Profiling First-Year Students in STEM Programs Based on Autonomous Motivation and Academic Self-Concept and Relationship with Academic Achievement," *PloSOne*, **9**(11), e112489 (2014)

- [18] Hutchison, M.A., Follman, D.K., Sumpter, M. and Bodner, G.M. "Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students," *Journal of Engineering Education*, **95**(1), 39-47 (2006)
- [19] Ciciarelli, B.A., Sherer, E.A., and Melvin, A.T., "ChemE Camp: A Two-Day Workshop to Increase Student Preparedness for Chemical Engineering Curricula." *Chemical Engineering Education*, **52**(3): 181-191 (2018).
- [20] Ciciarelli, B.A., Sherer, E.A., Martin, B.A., and Orr, M.K., "From Assessment to Research: Evolution of the Study of a Two-Day Intervention for ChemE Sophomores." 2020 ASEE Virtual Annual Conference, June 2020: Paper ID #30669.
- [21] Vogt, C.M. "Faculty as a Critical Juncture in Student Retention and Performance in Engineering Programs," *Journal of Engineering Education*, **97**(1), 27-36 (2008)
- [22] Komarraju, M., Musulkin, S., and Bhattacharya, G., "Role of Student-Faculty Interactions in Developing College Students' Academic Self-Concept, Motivation, and Achievement," *Journal of College Student Development*, **51**(3), 332-342 (2010)
- [23] Jaasma, M.A. and Koper, R.J., "The Relationship of Student-Faculty Out-of-Class Communication to Instructor Immediacy and Trust and to Student Motivation," *Communication Education*, **48**(1), 41-47 (1999)
- [24] Mamaril, N.A., Usher, E.L., Li, C.R., Economy, D.R. and Kennedy, M.S. "Measuring Undergraduate Students' Engineering Self-Efficacy: A Validation Study," *Journal of Engineering Education*, **105**(2), 366-395 (2016).
- [25] LAESE survey instrument developed as part of Assessing Women in Engineering (AWE) project: www.aweonline.org; NSF Grant #0120642. Marra, R.M. and Bogue, B., 2006. Women Engineering Students' Self-Efficacy: A Longitudinal Multi-Institution Study. *Women in Engineering ProActive Network*.
- [26] Concannon, J.P. and Barrow, L.H., "A Cross-Sectional Study of Engineering Students' Self-Efficacy by Gender, Ethnicity, Year, and Transfer Status," *Journal of Science Education and Technology*, **18**(2), 163-172 (2009).
- [27] Lee, W.C., Godwin, A. and Nave, A.L.H. "Development of the Engineering Student Integration Instrument: Rethinking Measures of Integration," *Journal of Engineering Education*, **107**(1), 30-55 (2018).