ASSESSMENT OF SHORT AND LONGER-TERM IMPACTS OF A 1-CREDIT CHEMICAL ENGINEERING FIRST-YEAR SEMINAR

Deborah S. Goldberg and Ganesh Sriram
University of Maryland, College Park • College Park, MD 20742

INTRODUCTION

Material and energy balances (MEB) is the first chemical engineering course in most chemical engineering undergraduate programs. The typical objective of MEB is to build a strong technical foundation of conservation principles and basic thermodynamics required for future chemical engineering courses. Not surprisingly, MEB introduces long, rigorous problems and solution methods that become increasingly complex as the semester progresses. This highly technical course structure can cause students to feel overwhelmed. Furthermore, the traditional 3-credit course structure of MEB also provides little space to introduce a "big picture" view of chemical engineering including its myriad applications and the variety of careers available to chemical engineers. Exclusion of these topics often leaves students with a poor appreciation of their major. In addition, students may not realize the work habits and resources that can help them succeed such as time management strategies and utilization of resources such as office hours. Finally, students may not appreciate the importance of engaging in co-curricular activities such as engineering clubs, undergraduate research, and internships, which are essential to build their resume for future opportunities. Failure to understand the major, diversity of career opportunities, valuable study skills, and the importance of co-curricular engagement can result in students questioning if chemical engineering is the right major for them, wondering if they can succeed in the major, dropping the major, struggling academically, failing to make a connection with peers and resources, and facing challenges when applying for jobs due to inadequate preparation.

To address this gap in the curriculum, we have developed, implemented, and evaluated a chemical engineering first-year seminar course. This seminar provides opportunities for students to learn about career options in chemical engineering and prepares students to apply for opportunities to gain engineering experience outside of the classroom. Based on literature reports on the importance of mentoring and instruction in academic habits for student success, we also included these attributes in the first-year seminar. Specifically, mentoring by successful upper-level students has been shown to positively impact first-year retention and academic success in engineering[1] and can be particularly impactful for women and underrepresented minorities.[2] In addition, instruction focused on time management and study skills in a freshman engineering class was shown to increase GPA and improve retention.[3] Including these elements in a single first-year seminar has the potential to produce positive effects on retention and academic success.

Deborah S. Goldberg, *PhD. is a senior lecturer in Chemical and Biomolecular Engineering at the University of Maryland, College Park. She earned her BS in chemical engineering, her PhD in bioengineering, and worked in the biopharmaceutical industry for six years before joining the University of Maryland in 2016. She developed and co-teaches the first-year chemical engineering seminar and has spearheaded initiatives including a peer mentoring program, pedagogical training of teaching fellows, and implementation of learning communities.*

Ganesh Sriram, *PhD. is an associate professor and chair of undergraduate studies in Chemical and Biomolecular Engineering at the University of Maryland, College Park. He oversees the undergraduate program and is committed to its continued improvement. He co-teaches the first-year chemical engineering seminar and has spearheaded departmental efforts including development of novel course modules, development of a manual of prerequisite concepts in chemical engineering, development of learning communities, and the pedagogical training of teaching fellows.*

To our knowledge, first-year seminars in chemical engineering were first reported in the 1990s. In 1991, Miller and Petrich[4] reported on a seminar at Northwestern University covering the roles of chemical engineers in various industries ranging from petroleum processing to polymers, electronics, and biotechnology. Each type of industry was illustrated by guest lectures, videos, plant visits, and student projects. In 1994, Myers et al.[5] introduced a seminar at the University of Dayton, motivated by the need to explain what engineering felt like and whether it was a good fit for the student. In this course, students in the semiunar met with faculty, staff, and other students from the department throughout the semester to learn about career opportunities, to hear first-hand from students and practicing engineers about their job experiences, to tour laboratories, and finally to meet with a faculty advisor for course registration. The student section of AIChE and upper-level mentors were involved in this course. Course evaluations indicated that this seminar was successful.

Overholser[6] and Bowman[7] reported two seminars introduced at Vanderbilt University in the early 2000s. These seminars focused on connection of first-year students to departmental faculty[6] and illustrating chemical engineering fundamentals through cutting edge research.[7] Example topics were semiconductor manufacturing, atmospheric particles, biopharmaceutical production, and molecular self-assembly. In a subsequent seminar implemented by Bowman,[8] the research focus was replaced by a "ChemECar" fuel cell car. Seminars at other institutions were more focused on logistical topics such as the first-year seminar at New Jersey Institute of Technology.[9] This seminar introduced students to a variety of useful information including departmental procedures, student organizations, co-op opportunities, undergraduate research, laboratories and process simulation, and lectures by industrial speakers. Peer mentoring was also an important component of this course. Although there was no formal assessment, informally collected course evaluation data indicated that most topics were well received by students. Multiple seminars were also implemented at Mississippi State.[10-12] Brannan and Wankat[13] reported the findings of two surveys relevant to the first-year experience—by the ASEE Freshman Programs Division (FPD) and the NAE Center for the Advancement of Scholarship on Engineering Education (CASEE)—on the first-year experience for engineering students in a number of schools. Recently, Ghorashi[14] reported analysis of a first-year course at Tennessee Technological University that focused on introducing the major through lectures and an industrial project while providing a good first-year experience and facilitating community building. This course was a modification of the original course developed by Arce and Visco, 15 years prior,[15] illustrating that at some universities, first year courses have been implemented and improved over time. Despite the presence of past publications, the 2016 chemical engineering curriculum survey report[16] does not mention first-year seminars, suggesting that seminars are likely not a standard part of the chemical engineering curriculum at most universities.

Overall, there have been many first-year chemical engineering seminars implemented, with a variety of course modules designed to comprehensively introduce students to the major, its rigor and its applications, while providing professional development and networking opportunities. A majority of these seminars reported success, mostly through informal surveys and occasionally through formal assessments, although rigorous analysis of chemical engineering seminars is largely absent from the literature. Preliminary work presented by us at the ASEE conference in 2019[17] focused on the design, implementation, and preliminary assessment of our seminar course. At that time, we had enrolled two cohorts and had not yet collected long term data. Our initial publication described some of the unique course elements including the engineering engagement activities assignment, personal roadmap assignment, and peer mentoring program. In the present work, we extend the analysis to include a third cohort of students and evaluate the longer-term impacts of the first-year seminar, analyzing data collected one year after completion of the MEB course as well as data from students who graduated.

METHODS

The goal of our seminar was to bolster student confidence in their ability to obtain a chemical engineering degree through a better understanding of what chemical engineering is and the habits of successful chemical engineering students. Therefore, we developed survey questions to measure those areas, focusing on three key measures:

1. Student understanding of the chemical engineering major and career opportunities.
2. Student understanding of practices needed to be a successful chemical engineering student.
3. Student confidence in getting a chemical engineering degree.

We designed our study to evaluate the impact of the seminar on these key measures by specifically considering the following research questions:

1. Were there any initial differences in the study's key measures between students who opted to take vs. did not take the seminar?
2. Did the seminar create short term increases in the study's key measures?
3. Did the seminar create longer term increases in the study's key measures?

Course Design and Implementation

The first-year seminar course was designed to help students answer several questions, namely, “What is chemical engineering and what can I do with a degree in chemical engineering?”, “How can I succeed in such an academically rigorous major?” and “How should I prepare for a career or graduate school after my BS in chemical engineering?” Course lecture topics and assignments were designed to support each of these questions. Table 1 provides a summary of the course topics and assignments. The seminar course was conducted once per week for 50 minutes in a collaborative classroom, and was co-taught by a senior lecturer and the director of undergraduate studies. The topics were packaged into 50-minute lectures held once a week during a 15-week semester. Additional details on the course assignments are available in the 2019 ASEE conference publication.[17]

Evaluation Methods

Cohorts. Data for the study was collected across three offerings of the seminar course in the 2017, 2018 and 2019 academic years. The seminar course is currently not required in the chemical engineering curriculum. The course was advertised during student orientation, and students had the option to register. Chemical engineering students who did not take the seminar course served as a natural control group.

In the first offering, the seminar and MEB were offered simultaneously in the same semester (Spring 2018). In subsequent offerings, the seminar was offered in the fall semester, and students took MEB the following spring semester. In our previous work,[17] we found that the average Likert score changes between pre-survey and post-survey were similar comparing concurrent vs. serial offerings. Since no significant differences on the impact of the seminar were found between the schedules, all three offerings have been combined here for analysis.

Surveys. Surveys were administered via Qualtrics® (https://www.qualtrics.com) and included quantitative and qualitative data collection. Pre-surveys were administered prior to the seminar for students taking the seminar, and prior to material and energy balances for students who were only taking MEB. Post-surveys were administered after all students had completed material and energy balances. Students earned course credit for surveys administered while they completed the seminar and/or material and energy balances. Students did not earn course credit for follow-up surveys in subsequent years, resulting in a lower completion rate. Survey questions and consent procedures were reviewed and approved by the University of Maryland Institutional Review Board. Some students declined to consent to the study, and their data was not included. Table 2 shows the total student participation in the study and the number of students who completed surveys.

Data Analysis

Pre and Post Data. Pre- and post-surveys contained eight Likert-style questions designed to probe student confidence in various aspects of being a successful chemical engineering student. Students rated the following statements on a

TABLE 1
Seminar Course Topics and Assignments

Question	Course Topics	Course Assignments
What is chemical engineering and what can I do with a degree in chemical engineering?	• Chemical engineering coursework and applications • Career paths in chemical engineering • Guest speakers from industry, academia and government	• Group project focused on chemical engineering companies • Personal reflection assignments on guest speakers
How can I succeed in such an academically rigorous major?	• Curriculum, 4-year plan and academic policies • Time management and project planning • Professionalism and team skills • Peer mentor panel and program	• Time management assignment • Engineering engagement activities
How should I prepare for a career or graduate school after my BS in chemical engineering?	• Student speakers on undergraduate research, internships, co-ops and study abroad experiences • Graduate school options and preparation	• Mock undergraduate research application • Mock internship application • Personal Roadmap assignment

TABLE 2 Student Participation in Study Across Three Offerings			
Cohort	**Total Number of Students**	**Number of Students Who Completed Pre and Post-Surveys**	**Number of Students Who Completed 1-Year Follow Up Survey**
Seminar + MEB	75	54	37
MEB only	119	68	53

five-point Likert scale from strongly agree (5) to strongly disagree (1):

1. I am confident I will obtain an undergraduate degree in engineering.
2. I am confident I will obtain an undergraduate degree in chemical engineering.
3. I know what chemical engineering is.
4. I am aware of the variety of career paths available for chemical engineers.
5. I have found an effective peer study group of chemical engineering students.
6. If I am struggling academically, I know where to turn for help.
7. I know what is required to get a good job after I graduate.
8. I can envision what I might like to do with my chemical engineering degree after I graduate.

A two-sample t-test was used to compare average student Likert responses between those who opted to take vs. did not take the seminar. This comparison was completed for each question in the pre-test and post-test separately. In each case, the null hypothesis was that there was no difference between groups, and a two-sided alternative hypothesis was used. Equal variances were not assumed for the two-sample t-tests. In addition, paired t-tests were completed within each group, comparing the post-survey to the pre-survey results with a null hypothesis that there was no change and a two-sided alternative hypothesis. In all cases, an alpha value of 0.05 was used as the cutoff for significance. This level of type 1 error has been used in other survey-based work[18] and is justified since recommending the seminar be continued based on a potential erroneous claim of statistical difference would be low risk. Alternatively, by reducing alpha we would increase type 2 error, potentially leading to failing to identify the impact of the seminar, which could prevent it from being continued. Statistical analysis was completed using Minitab® software (www.minitab.com). Qualitative data was collected in the post-survey of students who participated in the seminar. Student responses to each question were coded by hand, with multiple codes being applied to each response as appropriate.

One year follow-up data. Participation in undergraduate research, summer internships, and engineering clubs one year after completion of MEB was compared between students who did versus who did not complete the seminar course using a two-sample proportion test. Frequency of engagement with office hours and other resources was compared between the two groups using a two-sample t-test using a response scale of 4 points. In both cases, the null hypothesis assumed there was no change between groups and a two-sided alternative hypothesis was used with a significance level of 0.05.

Graduation data. Binary measures such as change of major were compared between groups using proportion tests while quantitative measures such as GPA were compared using t-tests. Both tests used the same hypothesis structure and significance levels as the 1-year data. All statistical analyses were completed using Minitab

RESULTS

Seminar Provides Significant Short-Term Benefits for Students, Many of Whom Were Less Confident to Start.

In order to assess short-term impacts of the seminar, we first analyzed if there was an opt-in bias that affected our key measures. Figure 1 shows pre- and post-survey responses to the eight key survey questions grouped by response types: agree (strongly agree and agree), neutral, and disagree (disagree and strongly disagree). Data is divided by students who enrolled in and completed the first-year seminar versus those who completed only material and energy balances. Pre-survey data indicates that students who opted to take the seminar were on average less confident in their knowledge of what chemical engineering is ($p < 0.05$) and the careers available to chemical engineers ($p<0.05$) compared to those who did not opt to take the course. In addition, students who enrolled in the seminar were less likely to have found an effective study group, know where to turn for help, or know what is required to get a good job upon graduation ($p<0.01$). These factors may have contributed to these students opting to enroll in the optional seminar.

Comparison of post-data indicates that despite starting at a less confident level, students who completed the first-

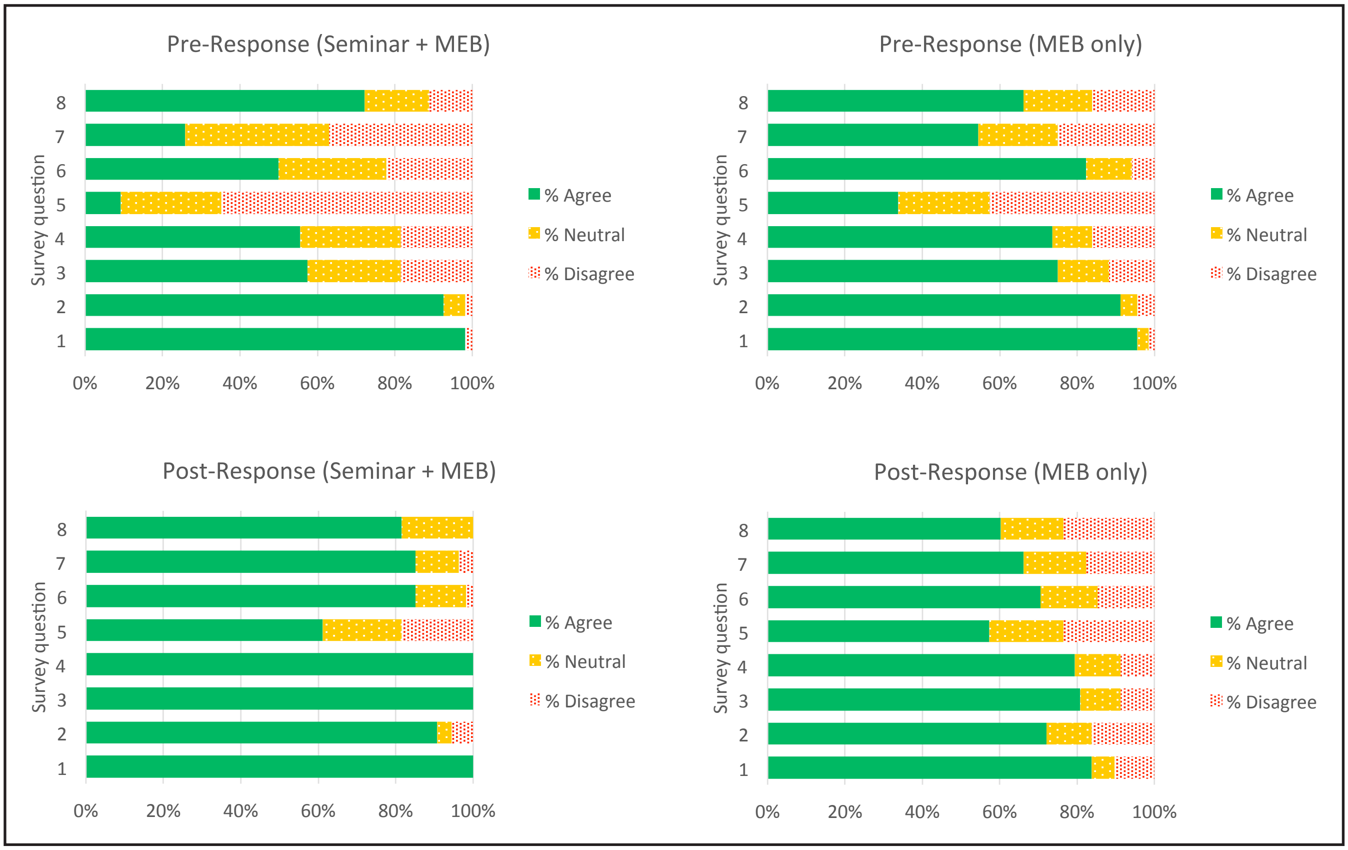

Figure 1. *Survey responses of students who took vs. did not take the first-year seminar before and after the seminar and MEB course.*

year seminar course had higher confidence in several metrics. Students who took the seminar showed significantly more favorable responses to all statements compared to those who took MEB only ($p<0.05$). The only exception was the response on finding an effective study group, in which there was no statistically significant difference. Viewing the data grouped into "agree", "neutral" and "disagree" responses, it is clear that the seminar led to a higher fraction of agreement with the statements on the post-survey, compared to taking MEB alone.

In addition to comparing pre- and post-data, we also looked at changes between pre- and post-surveys in each cohort using paired t-tests to better understand change on an individual student basis. Figure 2 shows the average individual Likert score change between the pre- and post-test, with a positive change indicating an improvement in the score. Remarkably, while the students who took the seminar showed no significant change in their confidence in obtaining a

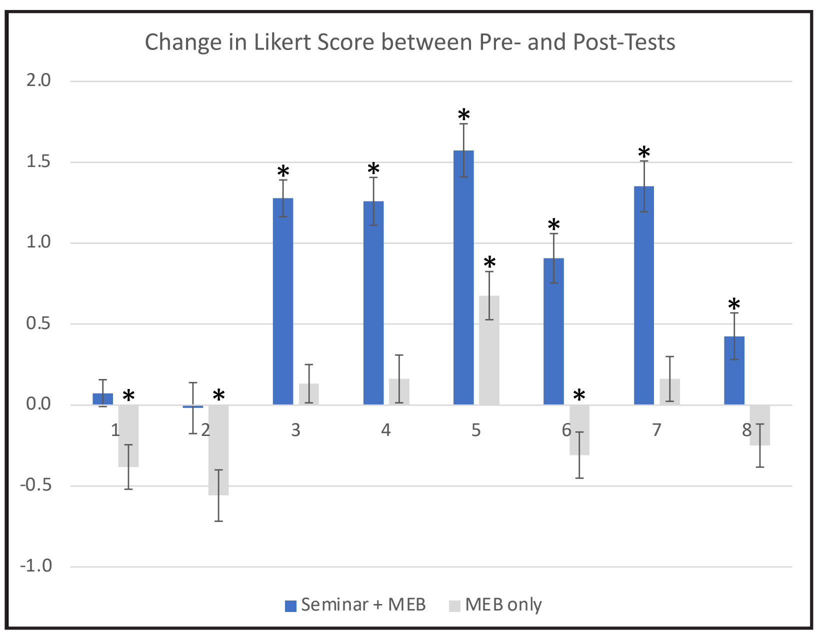

Figure 2. *Change in average Likert score between pre- and post-tests. Positive change indicates an increase in score. Error bars represent standard error of the mean. Stars indicate statistically significant difference between pre- and post-test (p<0.05) as determined by a paired t test.*

degree in engineering in general and chemical engineering in particular, students who did not take the seminar showed a drop in confidence in both metrics (average Likert score reduction of 0.38 for engineering ($p < 0.01$) and reduction of 0.66 for chemical engineering ($p < 0.01$). Students who participated in the seminar showed statistically significant improvements in knowing what chemical engineering is, understanding career paths, and knowledge of academic success-related factors such as knowing where to turn for help and understanding what is needed to prepare to obtain a job upon graduation. This data illustrates that participants derived significant short-term benefits from participation in the seminar course. Not completing the seminar led some students to question if chemical engineering was the right choice for them, and taking MEB alone did not improve student understanding of what chemical engineering is or the variety of career paths in chemical engineering.

Qualitative Data Shows That Seminar Students Learned About the Major, Career Opportunities, Habits for Academic Success, and the Importance of Perseverance.

In order to better understand the short-term benefits of the first-year seminar, we asked students who completed the seminar three free-response questions to assess their main takeaways from the course. The results are summarized in Table 3.

In response to the question "What did you learn about the chemical engineering field that you didn't know before?", students predominantly focused on the variety of career paths available to them. One student shared "*I learned just how expansive chemical engineering actually is and how there is a way for chemical engineering majors to assist in a plethora of different fields and job criteria. Pursuing chemical engineering really leaves the door open to any opportunities that may come your way*." Students also shared that they learned about a particular career path of interest and what chemical engineering is and isn't. The survey also asked students what they learned about being a successful chemical engineering student. The responses to this question were more varied, with students mentioning the importance of getting involved outside of classes, resources available to help students succeed, and the importance of time management, working with peers, and hard work. There were several undergraduate speakers and course assignments focused on how to get involved outside of the classroom and the importance of building your resume to prepare for a job or graduate school after graduation. One student remarked "*I learned that to be a successful chemical engineering student, you have to be willing to take risks and put yourself 'out there'. To be a successful chemical engineering student does not only encompass academics, although they do play a large role, but it includes research experience, co-ops/internships, and chemical engineering community involvement*." Finally, we asked students what they learned from their upper-level

TABLE 3
Student-Reported Key Takeaways from First Year Seminar

Survey Question	Coded Response	Count
What did you learn about the chemical engineering field that you didn't know before?	Variety of career paths	41
	Specific career path	10
	What chemical engineering is and isn't	7
What did you learn about being a successful chemical engineering student that you didn't know before?	Importance of getting involved outside of classes	16
	Resources available for student success	10
	Importance of time management	8
	Importance of working with peers	9
	Importance of hard work	5
What was the most impactful thing you learned from your peer mentor?	Information about future classes	12
	Advice about specific professors	4
	Advice on pursuing different opportunities	7
	Time management tips	6
	Study strategies	4
	Recommendations for specific resources	4

peer mentors. Data showed that upper-level students were able to provide unique insights including information on future classes, advice about specific professors, study strategies, time management tips, personal anecdotes on pursuing different opportunities, and recommended resources. Upper-level students were also able to share personal stories of perseverance, which was reflected in students sharing that their mentor taught them to keep trying. One student shared that they learned from their mentor "*that the CHBE classes get increasingly more difficult, but you also become more skilled so even if it seems impossible, not to give up because we'll be able to do more than we think we can*." This qualitative data helps to elucidate how the seminar was able to increase student confidence in a wide range of metrics.

Students Participated Equally in Activities One Year Later, Whether or Not They Took the Seminar Course.

All students were surveyed one year after completion of MEB to understand if completion of the seminar impacted their participation in various activities. As part of the seminar, students were required to attend office hours, use the engineering career center, and create mock research and internship applications, so we hypothesized that the seminar may increase participation in these activities in the longer term. Survey respondents were asked to share if they participated in undergraduate research, summer internships, or engineering clubs within the last year. There was no statistically significant difference in the proportion of participation in these activities between those who did and did not take part in the seminar course (data not shown). In addition, students were asked to rate the frequency at which they used office hours and the engineering career center on a four-point scale. Again, there was no statistically significant difference between the cohorts in this metric (data not shown). This data is somewhat surprising since there were many activities in the seminar course that were designed to encourage students to participate in undergraduate research, internships, and engineering clubs and take advantage of resources like office hours and the career center. However, students who did not participate in the seminar still engaged in these activities at a high level, perhaps due to diffusion of information within the student group or learning the importance of these activities from other sources such as advising meetings.

Seminar Students Had Similar Graduation Rates, Retention in Chemical Engineering and GPA Compared to Students Who Did Not Take the Seminar.

We analyzed academic data from the first cohort of students who graduated in Spring 2021 to better understand potential long-term impacts of the seminar. Graduation and retention data showed that 25/31 students who participated in the seminar graduated on time, with an additional five students on track for a delayed graduation due to completion of a co-op. Similar data was observed for students who did not participate in the seminar, with 19/21 graduating on time with one enrolled in a co-op. Note that nine students in the non-seminar cohort did not consent to the study, and their data is not included. 4/31 and 3/21 students changed their majors in the seminar and MEB only cohorts, respectively, with all new majors within the college of engineering. Therefore, the retention and graduation rates in both cohorts were excellent and similar. There was no significant difference in cumulative GPA for students who did (3.19) vs. did not (3.41) take the seminar course. Considering that students who enrolled in the seminar tended to be less confident in success in chemical engineering than their peers, this long-term data represents success of the seminar in producing similar successful outcomes for these students upon graduation.

Graduating Seniors Reflected Positively on the Impact of the Seminar on Their Undergraduate Experience.

According to survey responses, students who completed the first-year seminar felt that the seminar played an important role in many aspects of their undergraduate experience. Figure 3 shows how graduating seniors perceived the role of the first-year seminar in their personal and professional growth. Specifically, graduating seniors felt that the seminar was most impactful in helping them cultivate successful study habits and helping them decide if chemical engineering was the right fit. They perceived that the seminar also played an important role in connecting students to the department and with upperclassmen, and that it encouraged them to use resources such as office hours and the career services office. This data shows that graduating seniors perceived that the seminar was a meaningful part of their undergraduate experience.

DISCUSSION AND CONCLUSION

Creating a supportive environment for chemical engineering students that gives them the tools and resources to succeed academically and to embark on a rewarding career path after graduation is an important goal of chemical engineering undergraduate programs. In this work, we have shown that a first-year seminar course produces meaningful short-term impacts for students, helping them to understand what chemical engineering is, and the diverse career opportunities available to chemical engineers, while also connecting them with resources and opportunities which are important for their academic success and future career. Although the seminar was only 50 minutes per week, much of the work took

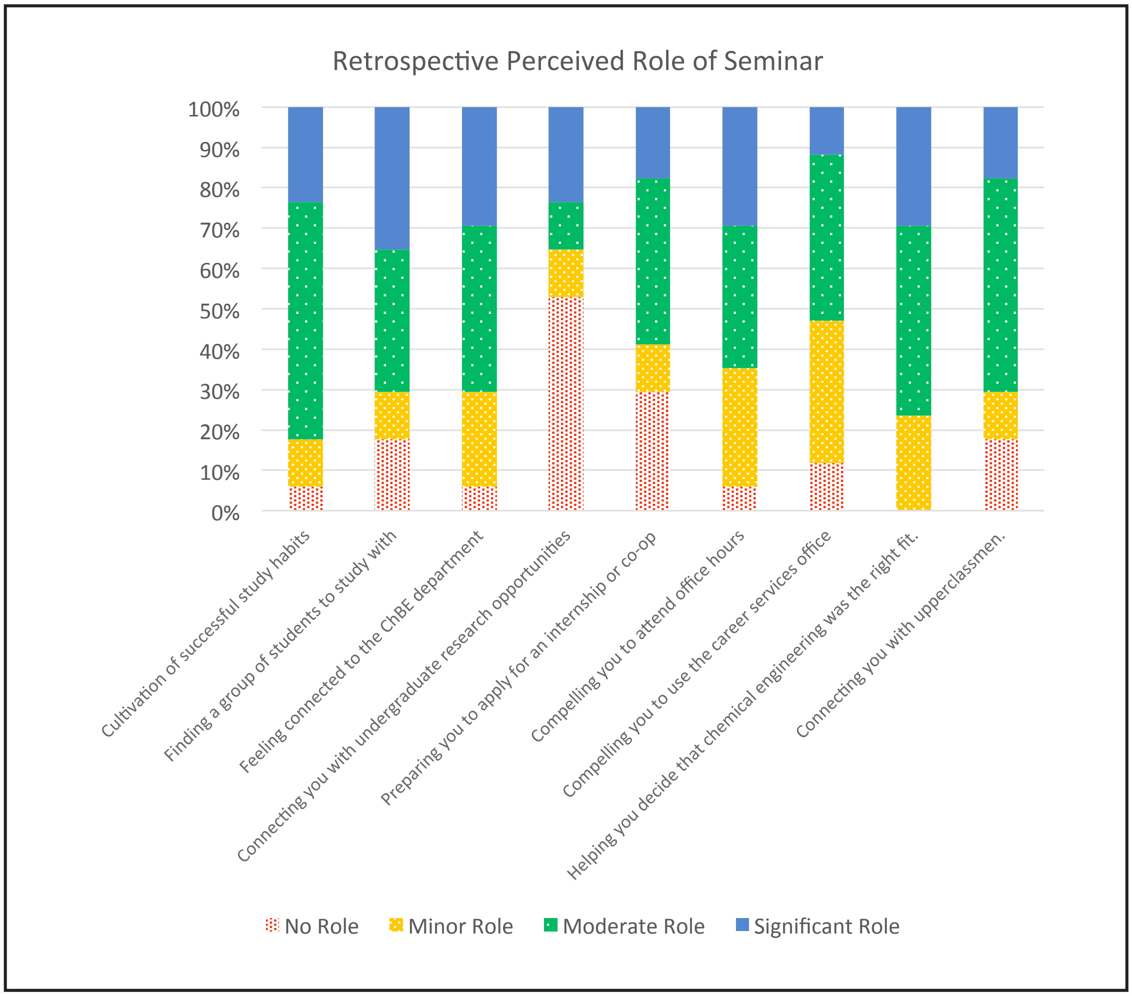

Figure 3. *Graduating seniors' perceived role of the first-year seminar in various positive outcomes.*

place outside the classroom – interacting with peer mentors, completing required assignments, engagement activities, and researching and reflecting on different career paths in chemical engineering. Perhaps most importantly, students who did not take the seminar experienced a reduction in confidence in their ability to pursue a chemical engineering degree. By one year after taking the material and energy balances course, students who did or did not take the seminar course participated in engineering activities at a similar rate and engaged with resources at a similar frequency, suggesting that students who did not take the seminar were still able to gain this knowledge, whether through peers, advising or another avenue. Although graduation data did not show significant differences in retention or academic success of students who did or did not take the seminar, seminar students looked back on their experience as an important factor in their undergraduate success. Therefore, while the main benefits of a first-year chemical engineering seminar may be in the short-term, such a seminar can be especially impactful for students who are unsure if chemical engineering is a good fit or have less confidence in their academic habits. Therefore, we encourage departments to consider offering a chemical engineering first-year seminar or incorporating elements of the seminar into material and energy balances in order to provide the best possible first year experience for students.

ACKNOWLEDGEMENTS

DSG and GS conceived of this study. DSG designed the course activities and assignments with assistance from GS. DSG and GS co-taught the seminar. DSG directed the study, conducted surveys, and analyzed data. DSG wrote and edited the manuscript, GS edited the manuscript. The authors thank Jinwang Zou for his contributions in establishing the data analysis methods used in this paper.

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