Work in Progress: Design, Implementation, and Evaluation of a 1-credit Chemical Engineering First-Year Seminar

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Abstract

In order to retain and graduate successful chemical engineering students, it is critical for departments to provide students with a clear understanding of the field and career options, connect students with resources to enable academic success, and assist students with gaining experience outside of the classroom. This can be difficult to accomplish through the standard curriculum, so these items are often left to advising sessions or supplemental events, resulting in many students not being fully informed on these critical topics. In this paper we will discuss the development, implementation, and evaluation of a first-year chemical engineering seminar course at the University of Maryland, College Park, designed to address these key areas to improve student retention and success. Students who completed the seminar course showed significant gains in several dimensions including understanding what chemical engineering is, appreciating the variety of career paths, recognizing which resources to access for help, and knowing what is required to get a job when they graduate; students who only took the standard Material & Energy Balances course did not show the same gains. Therefore, this work establishes the importance of a chemical-engineering specific first year seminar and provides guidance on how such a course could be designed.

Introduction

In most chemical engineering undergraduate curricula, the first departmental course taught to students is “Material & Energy Balances” (MEB), usually in the second or third semester. This course, by necessity, is technically heavy for the level at which it is taught. The resulting thicket of flowsheets, balances, and algebra leaves little room for providing introductory information about the major that could be crucial for students to connect with the major and succeed in it. For example, students who take MEB as their sole introduction to chemical engineering do not immediately realize the relationship between classical chemical engineering problems covered in MEB and the modern problems that engage today’s chemical engineers. As a result, they neither understand the myriad applications of chemical engineering nor the variety of careers in which chemical engineers are employed. Furthermore, while students quickly realize the difficulty of the major, they fail to recognize work habits and resources that enable them to succeed. This includes time and task management, assistance with planning an academic roadmap as well as information on co-curricular and extra-curricular activities that could develop one’s portfolio as a chemical engineer, such as research, internships, co-ops, study abroad and (chemical) engineering clubs. Finally, the curriculum does not typically provide early information on the steps necessary to prepare for one’s career. Failure to understand the answers to such questions can result in students dropping the major, struggling academically, failing to make a connection with peers and resources, and facing challenges when applying for jobs due to inadequate career preparation.

To address this gap in the curriculum, we have developed, implemented and evaluated a first-year seminar course at the University of Maryland, College Park. This seminar provides opportunities for students to learn about career options in chemical engineering, exposes students to academic resources, and informs them about opportunities to gain engineering experience outside of the classroom. This is done within the supportive context of a peer mentoring program and a collaborative classroom environment.

The 2016 chemical engineering curriculum survey report does not include first-year seminars[1], suggesting that seminars are likely not a standard part of the curriculum at most universities. A few chemical engineering first-year seminar courses have been developed[2,3,4], with a primary focus on applications of and careers in chemical engineering. Mentoring by successful upper-class students has been shown to positively impact first-year retention and academic success in engineering[5] and can be particularly impactful for women and underrepresented minorities.[6] In addition, instruction focused on time management and study skills in a freshman engineering class was proven to increase GPA and improve retention.[7] Combining these three elements in a first-year seminar has the potential to produce positive effects on retention and academic success.

In this paper we will discuss the development, implementation and evaluation of a chemical engineering first-year seminar course designed to 1) improve student understanding of chemical engineering and 2) provide tools and resources to encourage academic success and participation in resume-building engineering activities.

Methods

Course Design and Implementation

A 1-credit first-year seminar course named Exploring ChBE (CHBE100) was designed to help students answer the following questions: 1) What is chemical engineering and what can I do with a degree in chemical engineering? 2) How can I succeed in such an academically rigorous major? 3) How should I prepare for a career or graduate school after my BS in chemical engineering? The course was offered in a collaborative classroom with round tables designed to seat up to six students. Students were asked to sit at different tables each class and groups were asked to complete small exercises to facilitate development of peer relationships. The seminar was first offered during the 2018 spring semester, most recently offered during the 2018 fall semester and is co-taught by a full-time lecturer and the director of undergraduate studies. During each semester, an undergraduate teaching fellow assisted with course activities and grading. At this time, the seminar is an optional course open to first year students. Material & Energy Balances (CHBE101) was taught using “Elementary Principles of Chemical Processes” (Felder, Roussau and Bullard), and was delivered primarily via lecture with some active learning activities.

Table 1 summarizes the lecture topics and assignments included in CHBE100 (hereafter “seminar”) to address each of these questions. Several innovative course elements and assignments are described in more detail below.

Table 1. Course Topics and Assignments

Question	Course Topics	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 in after my BS in chemical engineering?	• Students 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

Time Management Assignment

Effective time management is challenging for students, especially with the demands of chemical engineering coursework along with out-of-class responsibilities. After a lecture focused on several different time management strategies, students were asked to track how they spent their time on an hourly basis for one week. Prior to the second week, students were required write a list of tasks that they needed to complete in the upcoming week and schedule the tasks in specific time blocks. Students then monitored their time for a second week, noting when they deviated from their plan. Finally, students reflected on the effectiveness of weekly time planning.

Engineering Engagement Activities

The Engineering Engagement Activities assignment was designed to give students experience in utilizing resources beneficial to their academic and professional success, with the hope that they will continue using these resources after the course ends. Students were required to complete the following activities during the semester: attend and report their experience with professor and teaching assistant office hours, attend a chemical engineering club meeting or event (AIChE student organization, Omega Xi Epsilon or ChemE Car), complete a resume critique at the engineering career center, register for the engineering career database, and attend a professional development workshop. These activities were aimed to improve student academic, departmental and career-focused engagement, respectively. To foster development of peer relationships, bonus points were offered for doing these activities with another student from the class whom they did not know previously.

Peer Mentoring Program

Academically successful junior and senior students were recruited to serve as peer mentors for first-year students in the seminar course. Mentors represented diversity in gender and ethnicity and included transfer students and students who had previously struggled academically. The mentors introduced themselves in an in-class mentor panel, sharing their individual experiences and their advice for succeeding in chemical engineering. First-year students were able to request a mentor after this panel discussion. Mentors attended several additional classes, participating in short activities with their mentoring groups of 3-4 students. Mentor groups were also required to complete an out of class outing such as bowling or eating a meal together. Finally, mentors were prompted to reach out to their mentees via email or text messaging several times throughout the semester to check in on mentee academic progress.

Mock Undergraduate Research and Internship Applications

After class sessions where upper-class students shared their research and internship experiences, first-year students were asked to craft mock applications for these opportunities. In the undergraduate research assignment, students were asked to find a faculty member of interest, summarize the group's research and then draft an email to ask to volunteer in their laboratory. For the mock internship application, students were required to find an internship posting, put together a resume and cover letter for the position and then reflect on what additional experience they could gain to be more competitive for the position. Individualized feedback on these assignments was provided during grading.

Personal Roadmap

As a culminating activity, students were asked to create a personal roadmap to graduation. Students were given a class period to work on the assignment supported by their peer mentors, professors, teaching assistant and academic advisors. Students first defined their goals including targeted graduation date, desired post-graduation plans (industry or graduate school) and desire to pursue a minor, double major, co-op or other special program. Students were then asked to make a plan on a semester basis on what they should be doing to achieve those goals across areas including coursework, activities, internships, undergraduate research. Example tasks included when to apply for particular positions, join clubs, complete undergraduate research, apply for graduate school, etc. Specific feedback was provided on the plans during grading.

Evaluation Methods

Cohorts

Three cohorts of students were surveyed to evaluate the impact of the seminar course. The cohorts are summarized in Table 2.

Table 2. Cohort Descriptions and Participation Rate

Cohort Name	Courses Taken	Semester	# of Students Enrolled in Courses	# of Students Enrolled in Study (Participation Rate)
Sem+MEB	Seminar, Mat & Eng. Bal	Spring 2018	34	25 (74%)
MEB only	Mat & Eng. Bal	Spring 2018	36	22 (61%)
Sem only*	Seminar	Fall 2018	21	21 (100%)

*Sem-only cohort will take Material & Energy Balances in Spring 2019 and will be compared with a final cohort comprised of students enroll in Material & Energy Balances in Spring 2019 who did not take the seminar course. These data are not available at the time of this publication.

Survey responses from Sem+MEB and MEB-only cohorts were compared in order to understand the impact of the seminar course on student understanding of the chemical engineering discipline, career options and strategies for success in and out of the classroom. Survey data from Sem+MEB and Sem-only cohorts were compared to understand how gains differed between students who took the seminar course prior to or simultaneously with Material & Energy Balances.

Surveys

Each cohort of students took pre-surveys at the beginning of the semester and post-surveys at the end of the semester in which they were taking only the seminar course, only Material & Energy Balances, or both. Surveys were administered online via Qualtrics and student identities were collected. Data presented includes students who completed both pre- and post-surveys. Baseline comparison using SAT scores ruled out any opt-in bias based on academic performance. Survey questions included likert-scale questions and free response questions; question wording is included in the results section. Follow-up assessments will be completed at yearly intervals to assess retention, academic performance, participation in engineering-related activities and eventual career placement. This work has been reviewed and approved by our institutional IRB, and appropriate consent was obtained for each student participant.

Statistical Analysis Methods

To understand whether cohort response changes were significant after taking the courses, three null hypotheses assuming no impact were set. For each cohort, changes between pre and post average likert scores were calculated and tested. A paired *t*-test was run for each question in the questionnaire, and $\alpha = 0.05$ was used as the cutoff for significance. In addition, to test whether the combination of Sem+MEB provided additional impact on students, two new null hypotheses were set. The first hypothesis was that Sem+MEB does not provide additional impact on students compared to Sem-only cohorts, and the second was that Sem+MEB does not provide additional impact on MEB-only cohorts. This involves calculating the changes in likert scores for each of the three cohorts and then comparing the changed scores between cohorts. For each of the two set of comparisons (Sem+MEB vs MEB-only, Sem+MEB vs Sem-only), Levene's test was first used to assess the equality of variance for changed scores in the two cohorts. After confirming the equality of variance, the pooled *t*-test was used to test the score differences for each of the questions. The level of significance was again set at 5%. For qualitative responses, student responses to each question were coded by hand, with multiple codes being applied to each response as appropriate.

Results & Discussion

Comparison of survey results between students enrolled in Material & Energy Balances who completed vs. did not complete the seminar course

The first offering of the seminar course during spring semester 2018 was available to all students registered for Material & Energy Balances. Approximately half of the students enrolled In material and energy balances elected to enroll the seminar course, creating a natural control group of those students who did not complete the seminar. It should be noted that because this control group was self-selected, there is the possibility of a bias in the results. Specifically, students who selected to enroll in the seminar may be keener about its outcomes or be more interested in the major. Nevertheless, we performed a baseline comparison using SAT scores, which allayed any concerns about opt-in bias based on academic performance.

Pre and post survey results scored on a likert scale of 1 (strongly disagree) to 5 (strongly agree) were compared for each cohort. Table 3 includes the question text, change in average likert score between pre and post-surveys and the statistical significance of this result based on t-tests. Figure 1 shows the pre and post likert averages and standard deviations for each question in Sem + MEB and MEB-only cohorts.

Table 3. Average likert score change between post-survey and pre-survey of Sem MEB and MEB-only cohorts. A positive change is an increase in score from the beginning of the semester to the end of the semester. A "*" indicates $p<0.05$ as evaluated by a *t*-test, and the absence of a "*" indicates $p \geqslant 0.05$ between post-test and pre-test.

		Sem + MEB		MEB only	
Q#	Question text	Avg. Change	p<0.05	Avg. Change	p<0.05
Q1	I am confident I will obtain an undergraduate degree in engineering.	0.24		-0.68	*
Q2	I am confident I will obtain an undergraduate degree in chemical engineering.	-0.16		-0.91	*
Q3	I know what chemical engineering is.	1.36	*	0.32	
Q4	I am aware of the variety of career paths available for chemical engineers.	1.36	*	0.45	
Q5	I have found an effective peer study group of chemical engineering students.	1.40	*	0.73	*
Q6	If I am struggling academically, I know where to turn for help.	0.76	*	-0.27	

Q7	I know what is required to get a good job after I graduate.	1.48	*	0.05	
Q8	I can envision what I might like to do with my chemical engineering degree after I graduate.	0.40		-0.45	*

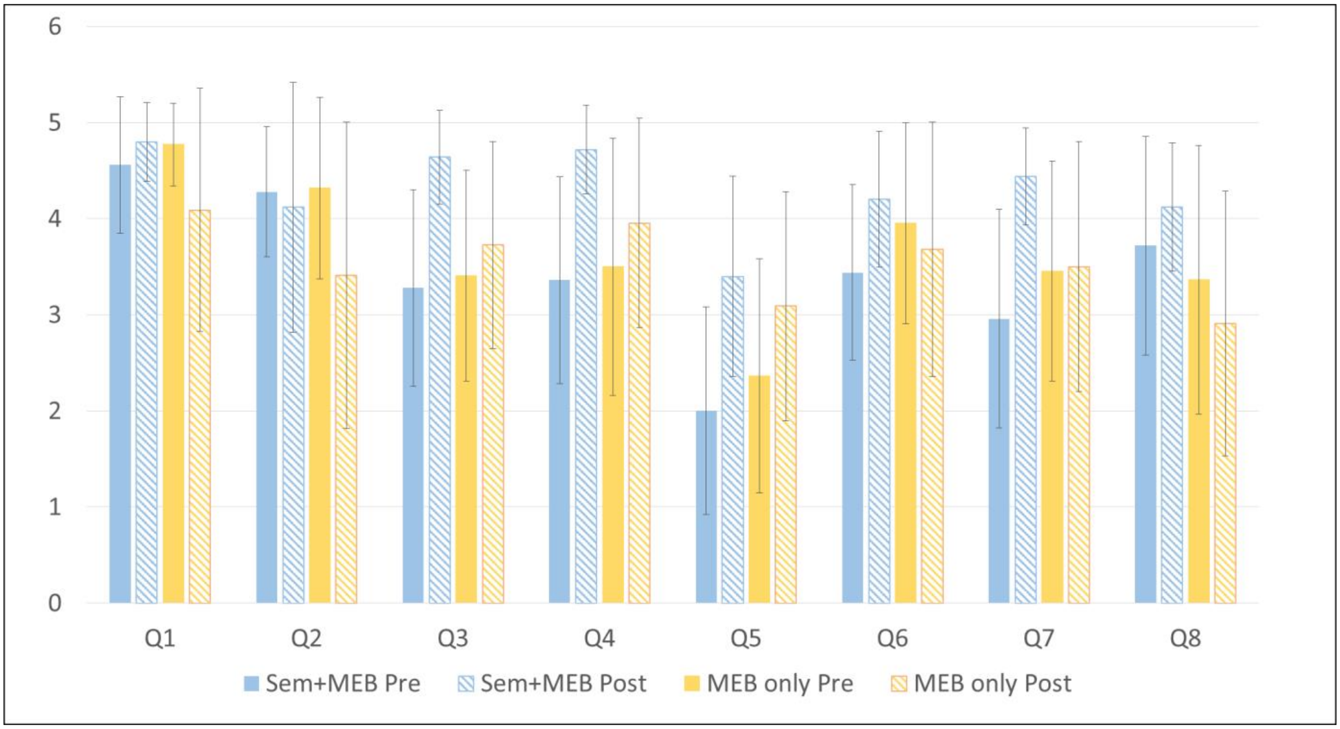

Figure 1. Pre and post-likert score averages for survey questions 1-8 in Sem+MEB and MEB-only cohorts. Standard deviations are shown as +/- error bars for each average.

With the exception of Q5 "I have found an effective peer study group of chemical engineering students," all pre-survey likert scores range from neutral to strongly agree, indicating that students in both cohorts start the semester with a positive perception of their knowledge of the chemical engineering major and field. Pre-survey averages for each question are similar between those who chose to enroll in the seminar and those who did not, indicating no significant difference between the two groups at the beginning of the semester.

Students who completed the first-year seminar class along with Material & Energy Balances showed either an increase or no significant change in likert scores across all 8 questions. The most significant changes were seen in questions that matched the seminar objectives including Q3 and Q4, focused on student understanding of what chemical engineering is and the variety of career paths available to chemical engineers. In addition, the data for students enrolled in the seminar shows increased confidence in finding peer study groups and knowing where to turn for help in the case of academic distress, two critical elements for success in upper level chemical engineering courses. Finally, students showed improvement in Q7, knowing what is required to get a good job when they graduate. These results support that the seminar design successfully delivered the course objectives.

In contrast, students enrolled in Material & Energy Balances only showed neutral or negative changes in most questions over the semester, most notably a statistically significant drop in their confidence to obtain a degree in chemical engineering or engineering in general (Q1,Q2). Despite completing a technical introduction to chemical engineering, their knowledge of the field of chemical engineering and related career paths did not improve significantly (Q3, Q4); in fact, they had less of an idea of what they wanted to do when they graduated compared to before taking the class (Q8). While students who took the seminar showed statistically significant gains in Q6 and Q7, MEB-only students did not show any improvements in these areas. Finally, MEB-only students showed gains in finding an effective peer group (Q5), although the effect was smaller compared with students who also took the seminar course.

In addition to examining the student changes over the semester within each cohort, an assessment was completed comparing the pre-to-post semester changes in each question between the two cohorts. All changes were found to be positive (seminar students showed more improvement or less decrease) and seven out of eight changes were statistically significant as shown in Table 4.

Table 4. Difference in Semester Changes between Sem+MEB and MEB only cohorts. A "*" indicates $p<0.05$ as evaluated by a *t*-test, and the absence of a "*" indicates $p\geq0.05$ between the average of the individual changes.

Q#	Question text	Average Change. Sem + MEB	Average. Change. MEB only	Change difference	p<0.05
Q1	I am confident I will obtain an undergraduate degree in engineering.	0.24	-0.68	0.92	*
Q2	I am confident I will obtain an undergraduate degree in chemical engineering.	-0.16	-0.91	0.75	
Q3	I know what chemical engineering is.	1.36	0.32	1.04	*
Q4	I am aware of the variety of career paths available for chemical engineers.	1.36	0.45	0.91	*
Q5	I have found an effective peer study group of chemical engineering students.	1.40	0.73	0.67	*
Q6	If I am struggling academically, I know where to turn for help.	0.76	-0.27	1.03	*
Q7	I know what is required to get a good job after I graduate.	1.48	0.05	1.43	*
Q8	I can envision what I might like to do with my chemical engineering degree after I graduate.	0.40	-0.45	0.85	*

When viewed from this perspective, the average change from the beginning to the end of the semester is higher for those who took the seminar class compared to those who took only material balances across all eight survey questions. These data further support that the seminar was effective in increasing student competence and confidence in chemical engineering.

In order to examine the data closer we also categorized individual student responses for each question into “negative change”, “no change”, and “positive change”, based on if the likert score decreased, stayed the same or increased, respectively, from the pre-survey to post survey for each individual student. Figure 2 shows the distribution of these individual student changes for each question in the two cohorts.

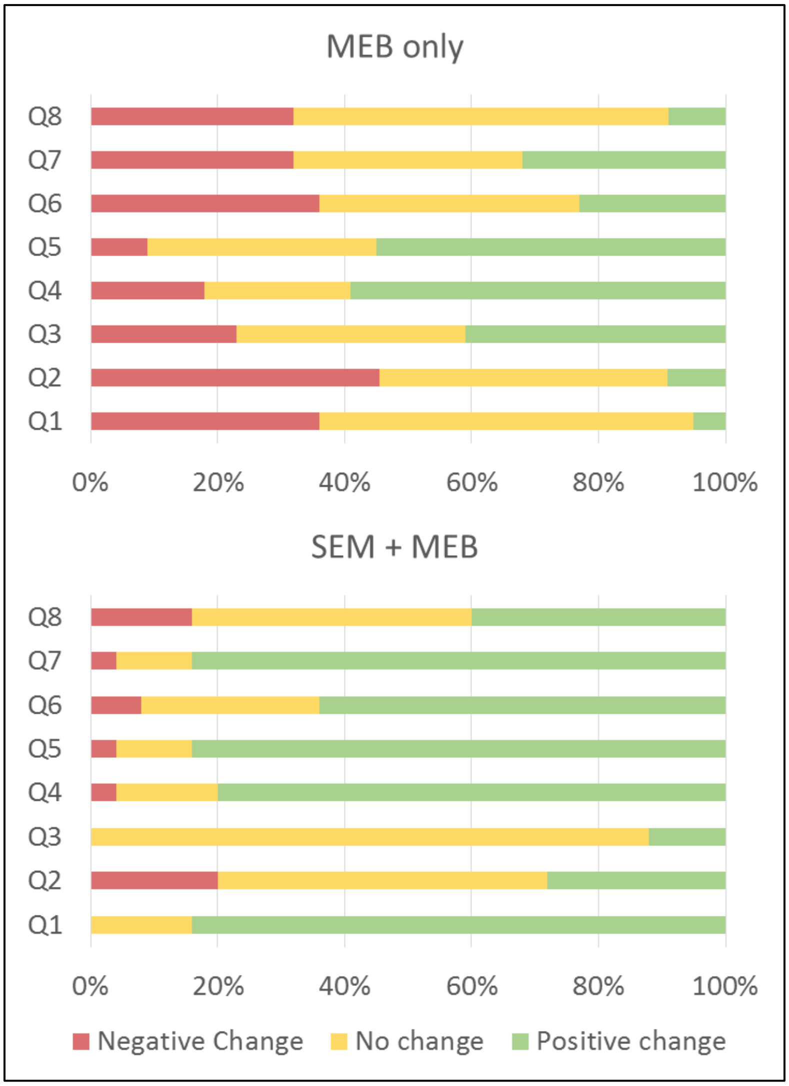

Figure 2. Histogram of individual student changes in each cohort. Proportion of x axis indicates the percentage of students in each cohort whose likert response decreased (negative change, red), increased (positive change, green) or stayed the same (no change, yellow) between the pre and post surveys.

The data supports that students who took the seminar course showed mostly no change or a positive change, while there were more negative changes observed for students who only took Material & Energy Balances. It should be noted that "no change" can be a good outcome, i.e., if scores remained unchanged at 4 or 5 since the beginning of the semester.

Additional analysis was completed on a second set of survey questions which probed students' likelihood of participating in engineering-related and career-preparatory activities. The survey questions are shown in Table 5 and the response data in Figure 3.

Table 5. Survey Questions probing intended participation in engineering-related activities

Prompt: Please rate your likelihood completing the following opportunities during your undergraduate career:	
Q#	**Prompt completion**
Q9	On-campus undergraduate research
Q10	Research internship at another University or institution
Q11	Internship in industry
Q12	Semester or year-long co-op in industry
Q13	Semester-long study abroad
Q14	Undergraduate teaching fellowship
Q15	Chemical engineering-related clubs such as American Institute of Chemical Engineers (AIChE), Chem-E-Car, or Omega Chi Epsilon (OXE)
Scale: 1- Probably not (<20% chance), 2- Possibly- 20-60% chance, 3- Probably (60-80% chance), and 4- Definitely (80-100% chance)	

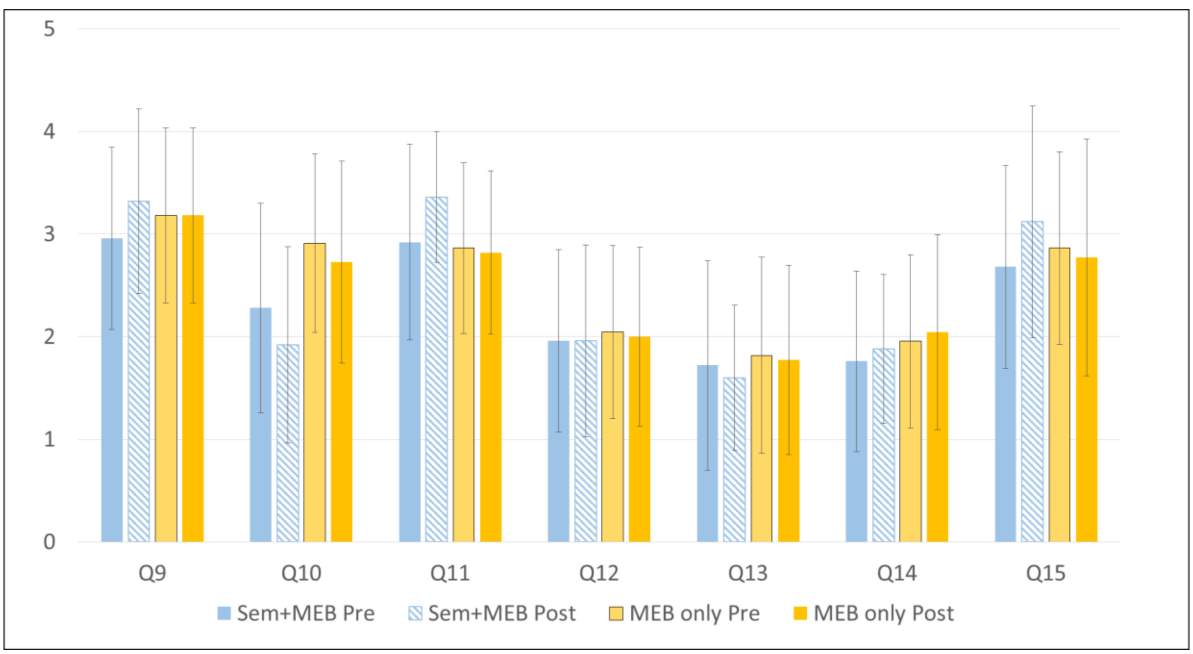

Figure 3. Pre and post-likert score averages for survey questions in Sem+MEB and MEB-only cohort for survey questions 9-15.

The responses for on campus undergraduate research, internships, and chemical engineering clubs were largely positive to start, and with the exception of Q11, which showed a statistically significant increase of 0.44 in the students who took the seminar class, there were no significant changes from the beginning to the end of the semester. This is somewhat surprising since the seminar class included student guest speakers sharing their experiences in internships, semester-co-ops, study abroad, and undergraduate research, in addition to assignments for creating mock applications towards these positions. It is possible that these course activities may have solidified students' desire to complete these opportunities rather than increasing them. Looking at categorized individual student changes for those who took the seminar (Fig 4), we see that many students did show increased interest in certain activities, especially undergraduate research (Q9), summer internships (Q11), and joining engineering student organizations (Q15). Another possibility is that as students became more informed about opportunities such as study abroad and semester co-op, they decided that these were experiences they did not want pursue. We plan to survey the students each year to track which engineering-related activities that they complete, so we will be able to determine if the completed activities match with the intended activities in this survey.

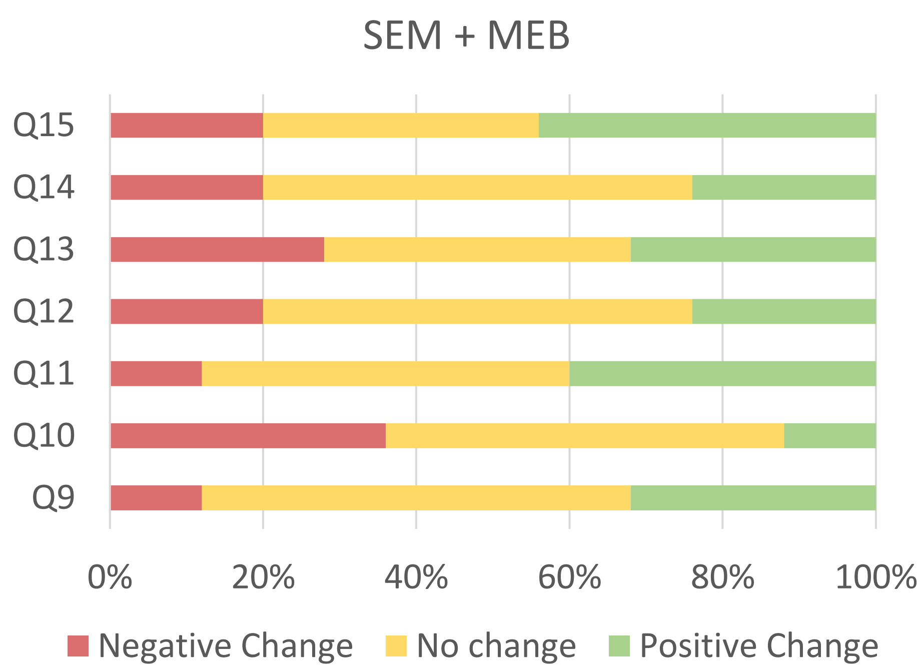

Figure 4. Histogram of individual student changes in each cohort. Proportion of x axis indicates the percentage of students in each cohort whose likert response decreased (negative change, red), increased (positive change, green) or stayed the same (no change, yellow) between the pre and post surveys.

Comparison of survey results between cohorts who took the seminar prior to or concurrently with Material & Energy Balances.

During the first offering of the seminar class, many students expressed that they thought that the seminar would have been more useful if it was offered prior to rather than concurrently with Material & Energy Balances. This prompted us to offer the seminar class during fall semester 2018 for chemical engineering students who planned to take Material & Energy Balances during spring semester 2019. Most of the students were freshman, although some were community college transfer students. The course content remained largely unchanged from the first offering. The same pre- and post- surveys were administered and compared with survey responses from students with those who took the seminar concurrently with Material & Energy Balances to determine if there were any significant differences.

As shown in Table 6 and Figure 5, changes across the semester were very similar for students who took the seminar class before Material & Energy Balances and those who took it concurrently. Comparison of the differences showed that the only statistically significant change between the cohorts was "I know what chemical engineering is" ($p=0.03$) which increased more for the students taking the seminar along with Material & Energy Balances (increase of 1.04) than those taking the seminar alone (increase of 0.60). This observation is not unexpected since students in the seminar only cohort have not yet taken a technical course in chemical engineering. Overall this data suggests that the seminar can be effective if it is offered before or concurrently with Material & Energy Balances.

Table 6. Average likert score change between post-survey and pre-survey of Sem + MEB and Sem-only cohorts. A positive change is an increase in score from the beginning of the semester to the end of the semester. A "*" indicates $p<0.05$ as evaluated by a *t*-test, and the absence of a "*" indicates $p\geq0.05$.

		Sem + MEB		Sem only	
Q#	Question text	Avg. Change	P<0.05	Avg. Change	P<0.05
Q1	I am confident I will obtain an undergraduate degree in engineering.	0.24		-0.24	
Q2	I am confident I will obtain an undergraduate degree in chemical engineering.	-0.16		-0.14	
Q3	I know what chemical engineering is.	1.36	*	0.76	*
Q4	I am aware of the variety of career paths available for chemical engineers.	1.36	*	1.19	*
Q5	I have found an effective peer study group of chemical engineering students.	1.40	*	1.57	*
Q6	If I am struggling academically, I know where to turn for help.	0.76	*	0.81	*
Q7	I know what is required to get a good job after I graduate.	1.48	*	1.14	*
Q8	I can envision what I might like to do with my chemical engineering degree after I graduate.	0.40		0.05	

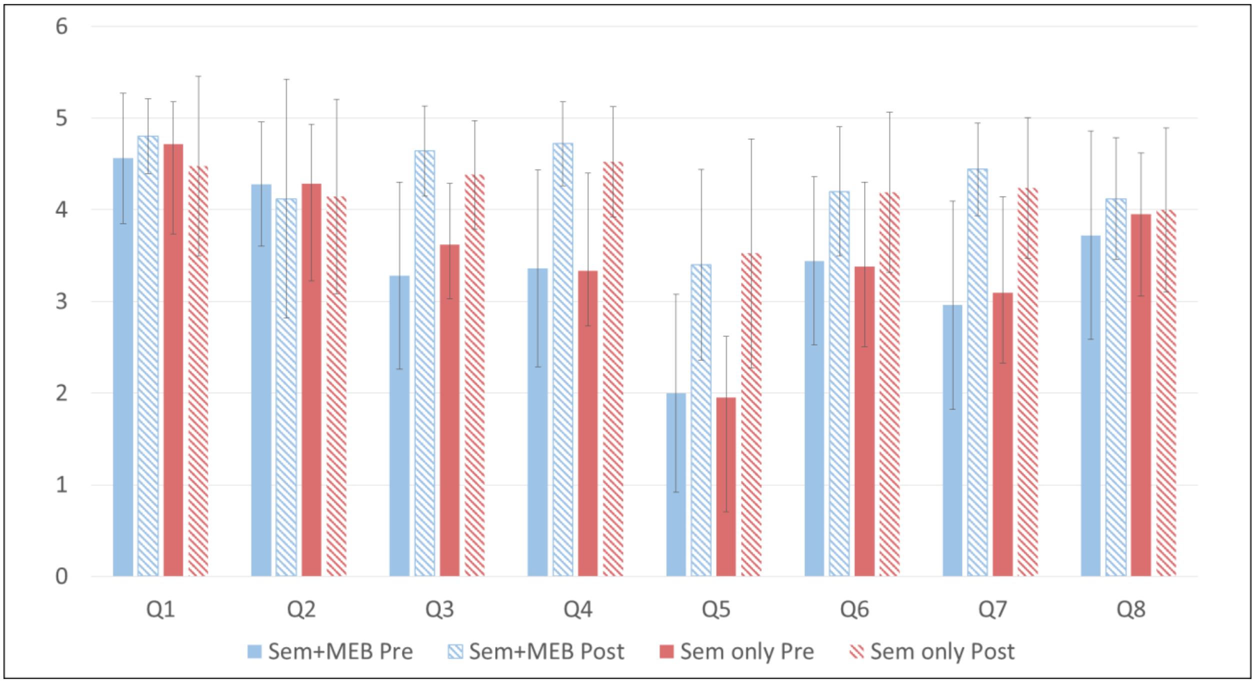

Figure 5. Pre and post-likert score averages for survey questions in Sem+MEB and Sem-only cohorts for survey questions 1-8. Standard deviations are shown as +/- error bars for each average.

Qualitative Analysis of Seminar Feedback

Students who completed the seminar class during either offering (n=46) were asked several qualitative questions at the end of the semester to better understand their experiences. When asked "What is the most important lesson you will take away from the seminar class" student responses included career opportunities, using resources, and the importance of completing engineering-related activities like undergraduate research and internships. Several students responded that the seminar showed them that while chemical engineering is a challenging major, they can succeed through hard work: "The most important lesson I will take away from the seminar is that although the curriculum is intensive and time consuming, it is not impossible to be successful. There are plenty of resources on campus, and instructors that want to see you succeed inside and outside of the classroom." Additional coded question responses and examples across both seminar cohorts are shown in Table 7.

Table 7. Coded Qualitative Question Responses with Examples

Question 1: What did you learn about chemical engineering field that you didn't know before?		
Code	Count	Sample Response
Diversity of career options	29	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.
Specific career option	9	The specialty chemicals industry is interesting and I may pursue it following undergraduate school.
What chemical engineering is	4	I really just learned what it is. Aside from the fact that it has something to do with chemistry, I had no earthly clue what it was or what I could do with a degree when I signed up for the major.
Question 2: What did you learn about being a successful chemical engineering student that you didn't know before?		
Code	Count	Example
The importance of completing engineering-related activities	12	I've learned that it's not only getting good grades that will set you up for success. Getting involved in different organization, conducting undergraduate research, and joining clubs, etc., are also part of being a successful chemical engineering student.
The importance of time management and study skills	10	The extent to which time management is not just helpful, but crucial to academic success.
The importance of peer collaboration	6	I learned that to be successful you have to form good study groups and collaboration.
The importance of using resources	6	I learned that when you don't know something, there are tons of resources we can turn to. Not only can we turn to the professors and the TAs, but we can similarly turn to our vast network of peers, both in our grade or ahead of us who have already experienced and survived whatever we are struggling with.
It takes hard work to succeed	5	It's going to take a lot of time and dedication to succeed.

In addition to the questions in Table 7, students were asked "How did this class impact your peer relationships with other chemical engineering students?" 39 of 46 responses indicated that the class had indeed improved their relationships with other chemical engineering students, either by helping them make new acquaintances or form new friendships. One seminar student responded "Definitely. Group projects have played an integral role in introducing me to my fellow students. It's nice to know more than 1 or 2 other people in my classes."

Overall, the qualitative feedback received on the surveys demonstrates that the seminar course met its desired objectives of helping students understand what chemical engineering is, the variety of career options available to chemical engineers, and how to succeed in chemical engineering both academically and through participation in engineering-related activities.

Conclusion and Future Work

In this paper we described the design, implementation and evaluation of a first- year seminar class in chemical engineering at the University of Maryland, College Park. The course addresses three key questions which are often left unanswered in the standard chemical engineering curriculum: 1) What is chemical engineering and what can I do with a degree in chemical engineering? 2) How can I succeed in such an academically rigorous major? 3) How should I prepare for a career or graduate school after a BS in chemical engineering? A combination of course lectures, group activities, student and industry guest speakers and assignments were included in the seminar course to address these questions. Pre and post-semester surveys showed significant student gains in categories that corresponded to the seminar objectives, establishing the effectiveness of the course. Students who did not complete the seminar and were enrolled only in Material & Energy Balances showed some negative changes in those same dimensions, most notably in their confidence in obtaining a degree in chemical engineering or engineering in general and being able to envision what they want to do with their chemical engineering degree when they graduate. This further supports the impact and importance of the first-year seminar. Similar gains were observed for students who took the seminar concurrently with or prior to Material & Energy Balances. Qualitative data from both seminar cohorts supports the quantitative findings. A possible criticism of our results is that students self-selected to enroll in the seminar and thus these students may have been more eager to receive its benefits; nonetheless it is clear that the seminar did provide significant benefits to those who chose to enroll.

We plan to repeat the analysis with new cohorts in the future to further support the conclusions with a larger dataset. In addition, follow up surveys will be administered at yearly intervals to assess retention, academic performance, participation in engineering-related activities and eventual career placement. We hope that this work will inspire other universities to consider developing a similar first year chemical engineering seminar courses to complement Material & Energy Balances and enhance the student experience.

Author Contributions

DSG conceived the study, led the instruction of the seminar, administered the surveys and wrote the manuscript. GS co-instructed the seminar and edited the manuscript. JZ performed the statistical analysis.

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