The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #41107

Board 75: Can Small Changes in Course Structure in Early Engineering Coursework Have a Big Impact on Retention?

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Can Small Changes in Course Structure Have a Big Impact on Retention in Early Engineering Coursework?

Abstract

Retention in collegiate engineering programs is a problem not specific to a single college or university, but across the engineering field, and this pilot study introduces a new approach for improving this retention issue. Studies report that up to 50% of students who begin an engineering degree program do not complete it, and this attrition is particularly high for students in their first and second years of engineering programs. Research suggests that a key contributing factor for why students leave the engineering field is the stress they feel from their coursework, yet considering how to alleviate this coursework stress is relatively unexplored. This study explores how to improve the negative stress responses students associate with early engineering coursework by restructuring the way the class is managed. Specifically, this study will test the efficacy of making small structural changes in an entry-level course to reduce the rigor shock students feel in introductory engineering courses and will qualify the impact those changes have on students' perceptions of engineering coursework and their decision to stay in the field. This study considers two different sections of a first-year engineering fundamentals course taught in a small midwestern university. Both sections of the course present the same content with the same general lectures, the same assignments, and the same assessments, but they are operated with different structures in terms of classroom management, assignment submission, and grading policies. Students' perceptions of their stress while taking the course will be captured upon course completion and the data will be quantitatively analyzed and examined through a constructivist lens to unearth new information about how these changes may impact student perceptions of their long-term self-efficacy in engineering and ultimately their decision to persist in the field. The data will also be reviewed to consider whether this impact differs for diverse student populations. This study is an early investigation into the impact of course structure on retention in engineering that will be used to help guide future work aimed at operationalizing how faculty can adjust their course structure to improve retention in engineering programs on a broader scale.

Introduction

Engineering degrees are notoriously difficult to complete, with studies reporting that just over half of the students who embark on a journey toward an engineering degree actually complete it [1]. Despite ongoing attempts to improve this situation, this trend has unfortunately not seen any sizable changes of late [2]. Studies have confirmed that lacking the academic skills to succeed is not the main driver for this attrition. Instead, rigorous coursework, a realization that they are not interested in the field, poor work-life balance, and stress have been identified as key contributors to why people leave engineering majors [3]. This pilot study aims to start a research-based conversation about the impact course structure can have on these factors - particularly on stress - and ultimately on students' confidence to continue in the field.

Background

Engineering program retention issues have been a popular area of research for the past two decades, and studies focused on understanding and improving the student experience for first-year engineering students are plentiful. Studies aimed at finding ways to make engineering coursework more engaging [4], building engineering-specific self-efficacy [5] - [7], better understanding incoming students knowledge base as a way of mitigating first-year stress [8], monitoring students' biological stress responses to engineering activities [9], and understanding student perceptions of their stress and anxiety in engineering coursework [10], [11] are just some areas that have been explored in the hopes of uncovering new avenues for faculty to consider in the design of engineering courses. This study will focus specifically on the impact of course structure on engineering-specific self-efficacy and stress.

Self-efficacy theory explains how people's beliefs about their ability to impact the outcomes they achieve are shaped. It suggests that these beliefs are shaped by mastery experiences, social persuasion, vicarious experiences, and physiological experiences. In turn, these beliefs impact cognitive processes, motivational processes, affective processes, and selection processes [12]. Related specifically to this study, self-efficacy can be explained as a measure of how confident students are in their ability to complete their engineering coursework and become an engineer, with implications ranging from how they feel when they are working on their engineering coursework to whether or not they ultimately continue to pursue the field. Related to the physiological experiences component of self-efficacy, stress can impact student's self-efficacy and has been found to be a concern specifically for students in their first year of engineering coursework [11].

While several studies have investigated the impact of self-efficacy and stress in engineering students [5] - [11], the idea of considering this stress as a function of course structure is relatively unexplored. In this pilot study, a first-year introductory engineering course was taught with two different structural styles to see if small changes in the way a course is structured may have a noticeable impact on students and warrant further larger-scale investigation. The impetus for this study was less rooted in theory than in ideological differences in pedagogy, however.

The introductory course used for the structural changes data collection was a first-year engineering course at a small, midwestern university. While the university itself is quite small, the engineering department is even smaller, with an average of only 25-30 incoming first-year students each year. These first-year engineering students all enroll in one of two sections of an introductory engineering fundamentals course (that includes both a lecture and a lab) that familiarizes them with engineering concepts and tools they will use throughout their four years of engineering coursework and in their engineering careers. One section of this course was taught by a professor who has taught this course for many years (Instructor A) and the other section of this course was taught by a new faculty member teaching it for the first time

(Instructor B). Since the goal is to have students obtain the same fundamental knowledge by taking either section of this class, both sections of the course were fundamentally set up with the same learning outcomes and used the same lectures, homework assignments, in-class activities, labs, and exams. However, when setting up the class, the instructors noticed that they had different perspectives on how these elements should be introduced and graded. Table 1 shows a comparison of the two professors who took part in this study and details how they structured their course in terms of their grading practices, how they set deadlines, and how they cultivate a classroom dynamic. This table also highlights personal and pedagogical differences between the instructors to inform readers of how these differences shaped their different course structures. It is important to note that while both instructors were confident in their own course structure decisions, they both also acknowledged the possible merit of the other instructor's strategy and were excited about the opportunity to optimize their course's structure based on the results of this ongoing work.

Table 1: Course Structure Differences between Sections

	Instructor A	**Instructor B**	*Key Differences*
Personal Background	Instructor A is an associate professor in the engineering department who has been in this role for seven years. She began working in this position after completing her Ph.D. specializing in biomechanics and mechanical engineering.	Instructor B (who is also the primary researcher for this study) is also an assistant professor in the engineering department but is in her first year in this role. She transitioned into this position after working as an engine design engineer for nine years, developing and teaching a high school engineering program for eight years, and completing her Ph.D. focused on engineering education.	*Instructor A has more experience teaching this course and working as a faculty member, whereas Instructor B has more experience performing engineering and teaching tasks in different contexts.**
Pedagogical Ideology	As the first and only woman in the department (who was relatively young when she began her career as a professor directly out of grad school), Instructor A consciously fine-tuned and structured a rigorous curriculum and classroom dynamic that would not only foster an efficient learning environment for first-year students but mitigate issues related to having a young woman engineering professor being "taken seriously."	As someone entering a faculty role in her 40s with significant experience in both engineering and education, Instructor B consciously worked to establish a more casual classroom environment that would foster learning through enthusiasm, engagement, and students feeling comfortable taking educational risks. While Instructor B firmly believes that holding students to the same standards as professional engineers (in terms of due dates, performance, etc.) is the goal of the collegiate engineering program, she believes this can be nurtured by allowing students time to learn, grow, and ramp into that goal mindset - especially in the engineering courses students will take in their first year.	*`The strategy employed by Instructor B is more casual and was deliberately selected based on her research related to engineering self-efficacy, whereas the strategy employed by Instructor A is more strict as a way of ensuring students took both her and the course seriously.***
Grading Policies	*Homework:* Instructor A's approach to grading homework includes precise, detailed rubrics with specific grading criteria to assess students' performance and proficiency with the topics they cover. With this method, students are rewarded for their attention to detail and correctness of solutions while also being given specific feedback on where they lacked understanding or detail. Grading rubrics were also posted with the homework assignments to be transparent and give students a clear understanding of what was expected of them *In-class assignments:* In-class assignments are graded for completion only and are due at the end of the class period. This strategy is used to encourage students to actively participate in the lecture activities and practice the skills that are being taught. *Attendance:*	*Homework:* Instructor B's approach to grading homework includes generalized rubrics that capture students' work toward becoming proficient with a given skill/concept. With this method, students are rewarded for their thoughtful application of the processes they have been taught over their solution correctness since the goal of the homework is for them to practice this new skill. *In-class assignments and attendance:* In-class assignments are not graded, but instead, students receive a daily grade for their attendance and active participation in the lecture and related activities (such as working on the in-class assignments) to encourage them to develop good "student" habits as they begin their college-level engineering coursework.	*The strategy employed by Instructor A offers more opportunities for students to receive specific feedback on their work at the cost of a significant amount of the professor's time spent in grading activities. The strategy employed by Instructor B reduces the time instructors need to spend grading but is slightly more qualitative and more challenging to ensure consistency with.*

	To encourage good habits for new college students, attendance is graded, with students earning points for being in class and losing points if they do not attend class (unless they have an excused reason for missing class).		
Due Date Policies	*Homework:* Homework content is broken into 20 assignments (with 1-2 assignments per week) to help students develop good time management and student skills in this introductory course. Assignments are due at 5:00 pm on their assigned due dates to simulate work-day deadlines. *In-class assignments:* In-class assignments are due at the end of the class period to encourage students to actively engage in new content.	*Homework:* Homework content is broken into only 10 assignments, which are due on Friday night at 11:59 for the weeks they are assigned. This strategy was set to allow students - a high percentage of which are student-athletes - time to complete their assignments around their other obligations. *In-class assignments* In-class assignments are not due or graded. They are meant only to help students begin to develop new skills that are taught in class and reinforced with homework assignments.	*Instructor A's strategy helps students stay on top of assignments and course content by introducing and collecting it in small increments, whereas Instructor B's strategy gives more freedom to students in terms of when they complete their work, at the possible risk of them putting things off and/or falling behind.*

* It should be noted that the only way a study such as this has real value is if faculty members are willing to consider their own practice with an open mind and are willing to adapt their teaching strategies based on what research suggests is ultimately best for students., which this study fortunately had.

** While a whole study could easily be devoted to why young women faculty members in engineering feel the need to justify their worth, this study will not focus on that element of the issue and instead present it here as a "why" for the course structure that was developed.

The main differences in the way the two instructors structured their courses were that Instructor A created a more structured classroom dynamic with more frequent due dates and deadlines (i.e. multiple times a week) and a more detailed grading strategy whereas Instructor B had a more casual classroom dynamic, less frequent due dates and deadlines (i.e. consolidated to only once a week), and a more qualitative approach to grading. This ideological variance sparked the idea of considering how these structural differences would impact students with the goal of beginning to understand which structural strategies may be better for students' stress, confidence, and ultimately their success and retention in the program. Clarifying if one approach offers a benefit to students would allow the instructors to set a clear path forward for this course (and others) that optimizes these factors for students. With this in mind, the overarching research question for this pilot study is:

How do differences in course structure impact a student's experience in the course in terms of their self-efficacy and stress?

This question will be examined through students' perspectives on stress and confidence and will be supported by referencing the technical knowledge they gained in the course, evidenced by their academic performance in the class.

Methods

For this pilot study, a multiple-methods approach was used to compare the impact of the different course structures used in two sections of the same course. A survey instrument that was developed to capture students' perspectives on learning, self-efficacy, and stress was used to collect both qualitative and quantitative trend data for this study. Once collected, the data were analyzed both qualitatively and quantitatively. Additionally, exam scores from student participants were retained as a way of measuring any impacts on knowledge/retention between the two different course structure strategies. Specific details of the data collection and analysis are presented in the subsequent sections along with a brief overview of the participants in the study.

Participants

All students enrolled in both sections of the Engineering Fundamentals course as college students (n = 29) were invited to participate in this study, and of those 29 students, 27 returned the necessary consent form for participation. Of the students who gave consent to participate, all those who remained in the class long enough to complete at least the first exam were offered the opportunity to complete the survey for the study, which resulted in 25 total participants. This cutoff was set to ensure student feedback reflected commentary from those who had enough time in the course to be able to speak to how the course's structure impacted them. Of the 25 participants, 23 completed the survey, three of which (13%) were women, three (13%) were Black, and two (9%) were Hispanic. The remainder of the students (65%) were white men. As noted previously, there were two sections of this course, and this was true for both the lecture portion and the labs portions of the class. Due to student scheduling variation, this means that some students had one professor for both lecture and lab or a combination of both instructors for the different portions of the course. Of the 23 participants, 5 students had *only* Instructor A, 5 students had *only* Instructor B, and the remaining 13 students had a combination of both instructors. The demographics of the students who had exclusively Instructor A or B were similar in terms of racial differences (with both sections having 80% white students and 20% students of color), but differed in terms of gender (with 2 women who exclusively had Instructor A and no women who exclusively had Instructor B).

Data Collection

Survey Instrument. At the end of the one-semester course, students who consented to be a part of this study were asked to complete an end-of-course survey via Google Forms that asked them to consider eight statements that assessed their perspectives on topics such as how much they learned, their engineering self-efficacy, and the stress they felt while taking the course. These statements (shown below) were evaluated on a 1-5 point Likert scale from 1 - Strongly Disagree to 5- Strongly Agree. An open-ended follow-up question *(Please explain your rationale for the rating you gave in the previous question.*) was also included after each statement to provide more context to the student's rating, allowing for a richer understanding of the data. The survey began with four statements developed to obtain general information from students about their experience in the course, as shown in statements 1-4 below.

1. This course was what I expected it to be.
2. I feel like I learned a lot in this class.
3. I liked how this class was organized/structured in terms of assignments, due dates, grading policies, etc.
4. Overall, I enjoyed this class.

Then, two statements were posed to assess students' self-efficacy in engineering (statements 5-6) and two statements were posed to assess students' feelings of stress while taking the course (statements 7-8). The self-efficacy-based statements (5-6) were adapted from the Self-Efficacy for Learning and Performance section of the Motivated Strategies for Learning Questionnaire developed by Pintrich et al. (1991) [13] to be specific to their confidence in engineering specifically.

5. I feel more confident in my ability to be successful in the engineering field after taking this class.
6. I am good at engineering.

Stress was assessed using statements 7 and 8, which were adapted from the Depression, Anxiety, and Stress Scale (DASS) [14], a widely-used metric developed by Lovibond and Lovibond in 1995 [11], [14]-[16], to align with the stress experienced as a result of a course.

7. I found this class to be stressful / I had a lot of nervous energy surrounding this course.
8. I found it difficult to relax into this course.

The data obtained from this survey were electronically saved and deidentified for analysis.

Exam Grades. Two exams were administered throughout this one-semester Engineering Fundamentals class, and the same exam was used for both sections of the class. In addition, a detailed rubric for grading each question in the exams was used for both sections of the course to ensure student concept understanding could be collected, analyzed, and compared directly.

Data Analysis

As noted previously, a multiple-methods approach involving both qualitative and quantitative data analysis was used for this study. Qualitative analysis was performed first, beginning by analyzing the open-ended responses from the survey instrument with in-vivo coding. The codes were then analyzed to find emergent themes in the data, as presented in Table 2. To support these emergent themes (and identify other areas of note), the responses to the Likert-scale ratings from the participants were next considered by averaging the ratings by section and instructor to show numerical trends that corresponded to the different course structures. Exam scores were also averaged by section as a final piece of supporting data.

Results and Discussion

The emergent themes that were discovered after one round of in-vivo coding of the open-ended responses to the survey questions are shown in Table 2 below. For most statements, the participant feedback was largely positive and consistent for both instructors and was not remarkable or noteworthy. Two statements, however, yielded themes that offered some insight into the impact of course structure on students, as shown in bold.

Table 2. Emergent Themes from Survey Responses

Question #	Category	Statement	Emergent Themes
1	General	This course was what I expected it to be.	Most students found this course to be what they expected it to be.
2	General	I feel like I learned a lot in this class.	Despite the varied levels of experience in engineering topics that students had as they began this course, students generally felt they learned a lot in this course.
3	**General**	**I liked how this class was organized/structured in terms of assignments, due dates, grading policies, etc.**	**Students were happy with how the course was structured overall but did note that they preferred Instructor B's structure with later submission times and weekly assignment dates (as opposed to Instructor A's earlier, more frequent submissions) so they could set up more of a routine.**
4	General	Overall, I enjoyed this class.	Students overwhelmingly enjoyed this class.
5	Self-efficacy	I feel more confident in my ability to be successful in the engineering field after taking this class.	Students grew in confidence and in their understanding of what engineering is through this course.
6	Self-efficacy	I am good at engineering.	Students generally felt confident in their skills as first-year engineering students, understanding that they still have a lot to learn within the field and have their own specific areas of growth to focus on.
7	Stress	I found this class to be stressful / I had a lot of nervous energy surrounding this course.	Students did not find the course to be overwhelmingly stressful but did note that they felt the most stress during projects.
8	**Stress**	**I found it difficult to relax into this course.**	**Students felt that there was a lot of work in this course, but many noted they were able to settle into the course once they became familiar with how it operated. Students in Instructor A's course were more likely to comment that it felt a lot was coming at them and required for this course, while Instructor B's students commented on feeling relatively relaxed despite the workload.**

These themes indicate that students did have a preference for how the course was structured and that these structural changes had an impact on the way they discussed the stress they felt with the course. The supporting quantitative results from the Likert-scale responses to each of the survey statements are shown in Table 3. Because of the small sample size and trend-identifying, supporting role of the quantitative data in this pilot study, a statistical analysis was not performed.

Table 3. Quantitative Results for Likert-Scale Survey Responses

	General Statements				*Self-Efficacy Statements*		*Stress Statements*	
	Question 1 This course was what I expected it to be.	**Question 2** I feel like I learned a lot in this class.	**Question 3** I liked how this class was organized/ structured in terms of assignments, due dates, grading policies, etc.	**Question 4** Overall, I enjoyed this class.	**Question 5** I feel more confident in my ability to be successful in the engineering field after taking this class.	**Question 6** I am good at engineering.	**Question 7** I found this class to be stressful / I had a lot of nervous energy surrounding this course.	**Question 8** I found it difficult to relax into this course.
Overall average	4.26	4.61	4.13	4.52	4.48	4.13	2.43	2.35
Average for students with Instructor A only	4.00	4.80	3.60	4.40	4.40	4.20	3.00	3.20
Average for students with Instructor B only	4.40	4.80	4.80	5.00	5.00	4.40	2.60	2.00
Delta between Instructor B and Instructor A students	0.40	0.00	1.20	0.60	0.60	0.20	-0.40	-1.20

The main trends that were observed front this data were as follows:

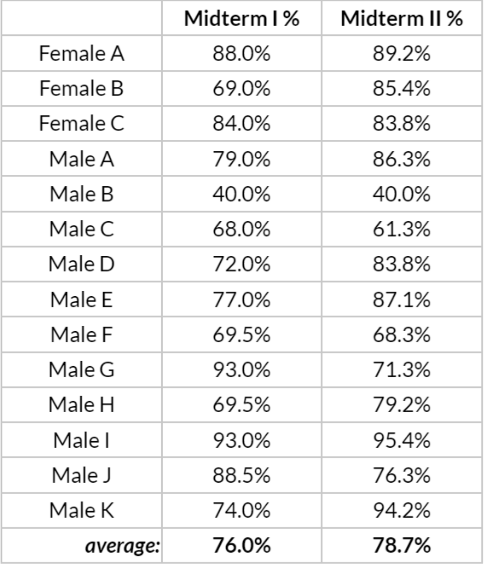
- The trend for the general statements was generally positive for course structure changes, with the largest delta seen in response to students' preference for the organization of the class.
- Student perspectives on learning were consistent between sections.
- Overall student enjoyment positively correlated with structural changes.
- Self-efficacy positively correlated with the course changes.
- Stress negatively correlated with the course changes.

This quantitative data supports the qualitative themes showing students preferred the course organization of Instructor B and that they experienced less stress with that structure as well.

One important element to reiterate when considering the self-efficacy trend in this data is that, as previously noted, there were two women in the Instructor A group and no women in the Instructor B group. This was an unfortunate yet unavoidable limitation of this pilot study based on the students who were enrolled in each section of the course. While one might argue that the difference in self-efficacy scores seen between instructors was related to the well-documented issue that women historically self-report lower self-efficacy in engineering than men [17]-[18], the women's responses in this study were at or above the median score when compared with the responses from the men in the study and therefore likely did not have an impact on the self-efficacy trend that emerged. It is also important to reiterate that this data represents a very small sample size and that these quantitative trends are only used to support the qualitative trends and to determine if there is merit to exploring this course structure impact at greater length with a larger study.

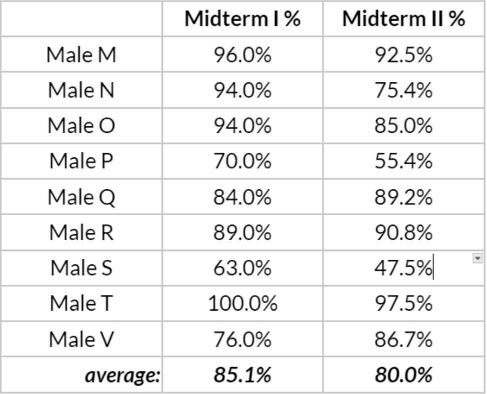
While the focus of this study is more on student stress and self-efficacy than academic performance and grades, exam scores were also considered as a way to gauge if the course structure would have an impact on the way students performed on summative assessments created to capture and assess student proficiency toward the learning objectives of the course. As seen in Tables 4 and 5, the exam scores for students in Instructor A's lecture trended slightly lower on average than for students in Instructor B's section. The higher student-teacher ratio in Instructor A's lecture section (18:1 vs 11:1 in Instructor B's section) was supplemented with a teaching assistant; however, this difference and its potential impact should be acknowledged when considering this result and others presented in the study. Also, with any small sample size of students in educational research, personal differences in students (such as experience levels, motivation, and studiousness) must also be acknowledged when considering these results. While the exam scores cannot be directly used to confirm the merit of one structure over the other, they can be used to support the previously seen quantitative result that the course changes do not compromise student learning.

Table 4: Scores for Instructor A students



	Midterm I %	Midterm II %
Female A	88.0%	89.2%
Female B	69.0%	85.4%
Female C	84.0%	83.8%
Male A	79.0%	86.3%
Male B	40.0%	40.0%
Male C	68.0%	61.3%
Male D	72.0%	83.8%
Male E	77.0%	87.1%
Male F	69.5%	68.3%
Male G	93.0%	71.3%
Male H	69.5%	79.2%
Male I	93.0%	95.4%
Male J	88.5%	76.3%
Male K	74.0%	94.2%
average:	**76.0%**	**78.7%**

Table 5: Scores for Instructor B students



	Midterm I %	Midterm II %
Male M	96.0%	92.5%
Male N	94.0%	75.4%
Male O	94.0%	85.0%
Male P	70.0%	55.4%
Male Q	84.0%	89.2%
Male R	89.0%	90.8%
Male S	63.0%	47.5%
Male T	100.0%	97.5%
Male V	76.0%	86.7%
average:	***85.1%***	***80.0%***

Conclusions and Continued Work

This pilot study offers preliminary results that indicate that course structure may be a valuable area to consider in the ongoing quest to find ways to improve engineering student retention. Specifically, it suggests that fostering a more casual classroom dynamic, setting deadlines that allow students to complete their required coursework around their responsibilities outside of the classroom (such as athletics, jobs, etc.), and employing a more qualitative, “is the general content understood” approach to grading may benefit first-year students in terms of their overall stress and confidence that they can succeed in the engineering field without being detrimental to the amount they learn. A continued, longitudinal study that investigates both if these trends are consistent over time and what other impacts structural course changes have on students may offer significant value in understanding this topic more broadly and ultimately help to improve the retention issue in the engineering field. Additionally, the proposed future investigations would benefit from the inclusion of perspectives on the prescribed structural changes from faculty and industry professionals and an exploration of factors such as the impact of students’ race, gender, and incoming engineering knowledge on these trends.

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