A Complementary Approach to Implementing Entrepreneurship into a Mechanical Engineering Senior Capstone Course Sequence

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Abstract

The exposure of students to entrepreneurship in an engineering context provides a range of valuable skills as they transition into their eventual careers. While not every student will start their own company and take on the role of entrepreneur, the ability to communicate ideas, innovate in product design, and generate value to all stakeholders are skills that are broadly applicable to a wide variety of engineering career paths, and these skills are mirrored in ABET student outcomes. As a project-based course focused on product development, a senior capstone course provides the perfect opportunity to implement teaching methods that emphasize the entrepreneurial aspects of engineering.

The present study attempts to incorporate numerous individual entrepreneurship modules to increase the scope and engagement of engineering entrepreneurship typically offered by any one of these exercises, while still retaining the benefits of modular implementation. The benefit of these individual modules is that they are self-contained and can be easily implemented into an existing course. In contrast to larger programmatic implementations, these small-scale modules are lower in cost and complexity, but also tend to focus on fewer aspects of entrepreneurship and are not necessarily reinforced by the surrounding course content.

This paper discusses the implementation of a number of engineering entrepreneurship exercises and activities into a mechanical engineering senior capstone course sequence. These modules take the form of 1) an e-learning module, 2) a series of guest lectures, and 3) a business competition. These modules were implemented for the first time in the 2018-19 academic year across a two-semester senior capstone course. In this implementation, the e-learning module and initial guest lectures preceded the initial business competition rounds in order to encourage and support student teams in their efforts to develop and communicate their business startup ideas, with the ultimate goal being the encouragement of engineering entrepreneurship. Student perceptions and self-assessment results are presented in order to quantify the effects of combining multiple business modules into a single course sequence.

Introduction

Incorporating entrepreneurship education into the engineering curriculum has seen a significant increase in recent years [1]. ASME Vision 2030, an effort to survey representatives from both industry and education on the strengths and weaknesses of mechanical engineering graduates, lists entrepreneurship and business processes among the most commonly cited missing components in ME curricula [2]. The ability of mechanical engineering graduates to meet the changing needs of employers depends heavily on the ability of these engineers to understand their customer in terms of economics, customer needs, and value proposition. Incorporating engineering entrepreneurship into the ME curriculum provides students with these skills and with the mindset necessary to better prepare them to enter the workforce [3].

One important reason to incorporate engineering entrepreneurship into the engineering curriculum is to spur innovation and promote interest in students to become entrepreneurs. Through this education, students gain the skills and perspective necessary to start their own businesses. These commercialization ventures have high growth potential and programs that foster these companies tend to mimic technology incubators [4] in an effort to kick-start the founding of companies.

These concepts of engineering entrepreneurship not only lead to the founding of new business ventures, but also provide significant benefits to student learning in their own right [5], [6]. This is evident in the alignment of entrepreneurship exercises with ABET student outcomes [7], as the product development process provides the broader societal context often lacking from traditional engineering coursework. Throughout the process of developing a product for commercialization and pitching this venture to potential investors, it is not difficult to imagine a wide range of ABET outcomes being addressed, in ways that traditional engineering curriculum is lacking. These exercises could align with ABET outcomes (2) *an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors*, (3) *an ability to communicate effectively with a range of audiences*, and (4) *an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.* The importance of new and different contexts for engineering decision making and communication is critical in the restructured ABET student outcomes and the opportunity for students to relate their engineering curriculum to a business setting facilitates this change of perspective.

In an effort to introduce and foster engineering entrepreneurship in the Mechanical Engineering curriculum at The Citadel, the most natural fit for these concepts was determined to be the senior capstone course sequence. In a capstone course, students are typically already working to develop a product to meet customer needs, which provides a realistic scenario and context to relate to engineering entrepreneurship content. Additionally, many of these seniors have already worked as interns in industry or government, which provides additional real-world business context that underclassmen may lack.

When surveying the wide variety of methods presented in the literature for implementing engineering entrepreneurship, both individual exercises (guest lectures [8], e-Learning modules [9], [10], business pitch competitions [11], [12], [13], dedicated courses [14], [15]) as well as more holistic approaches ([4], [16], [17], [18]) were found. For the purposes of introducing entrepreneurship into an existing course, incorporating individual exercises or modules seemed to be a more attractive option. These modules are primarily self-contained, providing for simpler course integration without requiring a complete course or program overhaul. These small-scale modules also did not seem to require the funding or wide-ranging support from other departments, schools, or industry often utilized in holistic entrepreneurship programs. On the other hand, these individual modules tend to incorporate just a few entrepreneurial learning outcomes and typically include just one teaching style (traditional lecture, flipped classroom,

etc.), compared to the more comprehensive nature of large-scale implementations. The question, however, was whether and to what degree the benefits of these larger programmatic implementations can be realized by combining multiple smaller-scale individual exercises in a single course. The self-contained nature of these individual modules allows them to be easily incorporated into an existing course, while still utilizing a range of teaching methodologies and teaching varied topics within engineering entrepreneurship.

The present study includes a discussion of the implementation of 1) an e-learning module, 2) a series of guest lectures, and 3) a business competition, into the Mechanical Engineering Capstone course sequence at The Citadel. These three separate methods for implementing engineering entrepreneurship will be referred to as business modules throughout the paper, for lack of a more accurate description of these activities. Each module will be discussed in more detail below. By combining a multitude of these modules into a single course, it is hypothesized that not only are the benefits of each exercise combined, but the student learning from one module can be used to inform the activities of the other modules. Ideally, the complementary roles that these learning modules play will encourage a deeper and more thorough interest in and understanding of engineering entrepreneurship than can be achieved with a single module alone. The present paper will discuss the implementation of these modules along with student perception and self-assessment data from the 2018-19 academic year.

Course Sequence

Senior design projects in the Mechanical Engineering Department at The Citadel are created as part of a two-semester senior capstone course sequence in which design projects are a mix of faculty-sponsored and department-sponsored projects from multiple departments on campus as well as projects fostered through industry partnerships with local companies. During the end of their junior year, students are presented with project ideas and have the opportunity to propose their own, after which each student ranks the projects according to preference. The faculty determines team assignments based on estimated necessary team size, funding availability, and this preference sheet.

The first semester of this course sequence focuses on design, while the focus of the second semester is building and testing a fully functional prototype. As students begin work on their projects during the first semester, these projects are framed to students as the initial product development process for a new startup. Using this motivation, students begin the course with assignments relating to developing the concept of the project, determining potential customers, analyzing the target market, and distributing surveys to determine critical customer requirements. After the project concept and target market is fully conceived, students are tasked with creating preliminary concepts in which they generate hand sketches or 3D models of different design permutations for major subsystems. Following this, each team performs a functional decomposition, engineering analysis, and unit cost analysis in order to determine the criteria by which their preliminary designs will be compared. Using these criteria, each team selects a final design concept, generates a detailed final design, and creates a bill of materials to be ordered over the break between fall and spring semesters. Upon design completion, each team generates

a final design report as well as a final design presentation that is delivered to the entirety of the ME senior student body and available mechanical engineering faculty.

At the beginning of the second semester, each team is tasked with identifying a short-, medium-, and long-term milestone in the development of the design prototypes. Throughout the semester, each student design team presents their prototype at these pre-defined milestones, demonstrating functionality of various subsystems as they are constructed. After nine weeks, students begin transitioning from the construction phase into the testing of their prototypes, developing a plan of experimentation to test the feasibility and performance of the critical customer requirements set forth at the beginning of the course sequence. This experimental data is then compared with theoretical predictions generated as a part of the engineering analysis during the design phase. At the end of the semester, each team presents their final prototype and comparative engineering analysis to the ME senior students and available mechanical engineering faculty.

During the 2017-18 academic year, a number of Mechanical Engineering senior capstone teams chose to enter an existing campus-wide "Shark Tank"-style business competition hosted by the business school, presenting their senior capstone projects as business ideas. A few of these teams progressed through the rounds of this competition and gained valuable experience in communicating their engineering design and business idea with one of the mechanical engineering senior capstone teams eventually winning the competition.

Because of the success of these teams, it was decided by the ME faculty that for the 2018-19 academic year, entry into the competition would be compulsory for all ME senior capstone teams and additional entrepreneurship content would be sought out to further support and promote the educational benefits seen by the initial group of students. The content and implementation of the three business modules included in the 2018-19 academic year are discussed below.

KEEN e-Learning Module

An e-learning module developed as part of a project through the Kern Entrepreneurial Engineering Network (KEEN) was deployed in the Mechanical Engineering senior capstone course sequence during the Fall 2018 semester. This e-learning module is named, "The elevator pitch: advocating for your good ideas," and was integrated into the learning management system for the course. The module is broken into 4 lessons, which focus on identifying stakeholders and their needs, criteria of a successful pitch, developing a pitch, and persisting through failure, respectively. Each lesson contains a series of slides, links to articles, videos, and journal prompts and takes approximately 20-40 minutes to complete. The online implementation of this business module allowed the instructors to incorporate a flipped classroom approach, in which students were responsible for completing the lessons outside of class and in-class time was used for supporting exercises and activities, described below.

In order to encourage the students to start creating a cohesive vision of their projects, this e-learning module was implemented over the first two weeks of the course. On the first day of the course, the students were introduced to the KEEN module. Each of the 4 lessons was followed by a short review quiz, so students were responsible for reviewing all content of a lesson and completing the review quiz for that lesson before each of the 4 following course meetings.

Students were also given an assignment of generating an elevator pitch to be delivered in front of the class after all of the KEEN lessons were completed, as a goal to build toward throughout this module.

During the second course meeting, after students had reviewed the lesson on stakeholders, a contextual activity was introduced in which students broke into design teams and were prompted to think of as many potential customers for their product as possible in 5 minutes and write each one on a separate sticky note. Once this was completed, the students had an additional 3 minutes to group these customers into major categories (i.e. educators, industrial manufacturers, etc.). Next, the design teams were prompted to try to think of the value that their products delivered to those customers and what their most important customer requirements might be. From this, the students were asked to share their biggest customers and what design features might be important to them. Afterwards, the students were given an assignment in which they had to develop a sample survey to distribute to potential customers.

At the third course meeting, students were first asked to define and discuss exigency, an urgent need or demand for their product, a term that had been featured heavily in the second KEEN lesson. Students were then asked to create a list of criteria for a successful sales pitch. To reinforce this, a series of pitches from the TV show “Shark Tank” were shown to the students, including the companies CitiKitty, Shell Bobbers, Scrub Daddy, and Ionic Ear. These four pitches had varying levels of success, with CitiKitty and Scrub Daddy making the best argument for exigency and Ionic Ear being bad in almost every aspect. After each pitch, the students were asked to choose from their list which of the criteria of a successful pitch were used by those pitching and what they did that was not successful. After this, students broke into teams to discuss the exigency for each of their products.

During the next course meeting, students developed a message map, which listed 3 key benefits of their products and then supported each of those benefits with examples, data, or anecdotes. Once each team completed this, they followed the format given in the KEEN lesson to start outlining an elevator pitch, with 1-2 lines to argue for exigency, 3-4 lines about the concept of their product, 1-2 lines describing the value proposition to the customer, and 1-2 lines that conclude and make a request. During the fifth course meeting, students described what criteria could make a pitch unsuccessful and the class discussed ways to recover or deal with these difficulties. Next, common criticisms that potential investors might make during an investor pitch were discussed. After this, the students broke into design teams and separated to other classrooms to practice elevator pitches to each other.

During the sixth course meeting, students were asked to deliver elevator pitches to the class. This class period was not long enough for every student to pitch, but every student was expected to be prepared to deliver a pitch for their group. To accomplish this, the names of each member of each team were listed on slips of paper in a separate cup for each team. A team member was drawn at random for each team to deliver the pitch for their team. Once all teams had pitched, the process repeated and a second team member was drawn, and this process repeated until the class period ended. At the end of each pitch, the audience of students and professors was free to ask questions of the pitcher. Afterward, a common criticism was drawn at random from slips of

paper in a separate cup. These common criticisms were taken from a journal prompt in the fourth KEEN lesson. The pitching student had to respond to this criticism in order to be able to assess each student's ability to recover from an unsuccessful pitch, despite the fact that the pitch itself may have been quite successful.

Guest Lectures

In an effort to connect the engineering curriculum to the confluence of engineering and business seen in industry, a series of guest lectures were arranged at The Citadel during the 2018-19 academic year. These guest lectures were given by a graduate of The Citadel, who is currently employed as a senior executive at an American aerospace manufacturer. This business module consisted of four guest lectures across the two semesters of the senior capstone course sequence.

The first of these lectures began with a discussion of the current and upcoming product offerings of the company as well as the process by which this aircraft manufacturer evaluates the product offerings of both themselves and their competitors. This included the method for quantification of critical performance criteria and comparison of performance versus price, which allowed for the identification of gaps in the market. This lecture occurred early in the first semester of the course sequence and due to scheduling conflicts occurred after students turned in assignments relating to market identification and customer requirements. Still, this lecture built upon concepts introduced to students in the e-learning module and in-class lectures.

The second lecture occurred in the middle of the first semester and introduced students to the financial justification that the guest lecturer used to propose new product lines to the CEO of the parent company. This included a discussion of concepts like Internal Rate of Return, Net Present Value, and Break Even, which are used to judge the viability of these new products. These concepts were discussed in theory and presented along with a sample business case to show how these values are calculated for a new plane at this aircraft manufacturer. After this lecture, students were asked to complete an assignment in which they modified a spreadsheet from the presented business case in order to develop the financial justification for a theoretical new product line that met a different market segment. Both of these first two guest lectures occurred before entry forms to the initial round of the business competition were due.

The third guest lecture occurred in the beginning of the second semester of the course sequence, after the first two rounds of the business competition were completed. This lecture incorporated a unit cost analysis submitted by one of the capstone teams during the first semester. This cost analysis was used to develop a new sample business case, along with a discussion of recurring versus non-recurring costs and costs of research and development, tooling, facilities, labor, and materials.

The fourth guest lecture occurred in the middle of the second semester of the course sequence and included both the original guest lecturer as well as a very experienced executive recruiter that has worked in coordination with the aircraft manufacturer and the aerospace industry at large for a number of decades. This lecture included a discussion of the hiring practices common to the aerospace industry, the importance of networking, and strategies for business communication,

which included interview skills as well as general approaches to how to communicate in an entrepreneurial setting.

Business Competition

The Citadel offers an annual business competition hosted by the business school which student teams or individuals from all disciplines are free to enter. The team that wins the competition receives a $10,000 prize and second place receives a $5,000 prize. In addition to requiring all Mechanical Engineering capstone teams to submit entry forms for the initial round of the competition, bonus points are awarded to those who make it to the semifinals and additional points are awarded to those that make it to the finals, in order to further incentivize teams to do well.

The first round of this competition involves submitting a written summary of the proposed business idea, which includes a brief discussion of the business concept, target market, competition, and value proposition. These business summaries are evaluated by a panel of judges, which includes both engineers and businesspeople from local industry. From the submissions in this initial round, ten semi-finalists are chosen.

In the semi-final round, each of the ten teams presents a three to five minute oral elevator pitch to a panel of judges. During this presentation, no props or slides are allowed to be used and teams are free to choose who and how many members from the team presents. After the presentation is over, judges are given the opportunity to ask questions to the students about the proposed business. These questions often touch on subjects such as the target customer, market competition, revenue model, and intellectual property. This portion of the competition occurs near the end of the fall semester and finalists are announced shortly thereafter. From these ten semi-final teams, five are chosen to progress to the final round of the competition.

Each finalist team is assigned a business mentor, who comes from the local business community or business school faculty. Throughout the entire second semester of the course sequence, the finalist teams meet with their business mentors one night per week and work toward developing a full business plan. The final round culminates in a 45-minute presentation in which students are allowed to use slides, demonstrations, and props of any kind to make an argument for their company to win the competition and receive investment.

In the 2017-18 academic year, 8 mechanical engineering senior capstone teams chose to enter the business competition. From these teams, mechanical engineering senior capstone teams accounted for 4 of the 9 semifinalist teams and 3 of the 5 overall finalist teams. One of these mechanical engineering teams went on to win the competition.

Because of this success, in the 2018-19 academic year entrance into the business competition for all 14 mechanical engineering senior capstone teams became mandatory. From these 14 teams, 7 advanced to the semifinal round, making up 7 of the 10 total semifinalist teams, and 4 of the 7 mechanical engineering teams advanced to the finals, making up 4 of the 5 total finalist teams. The winner will be announced near the end of the Spring 2019 semester.

Assessment and Results

During the middle of the second semester of the 2018-19 capstone course sequence, a 31-question survey was administered to the students in class and students were encouraged to give honest feedback, as the survey had no impact on their grades. This survey was given after completion of the e-learning module, all guest lectures, and the initial two rounds of the business competition. The survey received 67 responses, which constitutes all but one student in the course. These surveys were administered anonymously, although students were asked to report which design team they were on in order to be able to track responses against team performance, such as progress in the business competition. From these 67 respondents, 18 students were a part of teams that made it to the final round of the business competition, 32 students made it to at least the semifinal round, and the remaining 35 students did not make it past the initial round of the competition.

All questions on the survey used a 5-point Likert scale, where 1 stands for strongly disagree and 5 stands for strongly agree. From the 31 questions, 5 assessed learning outcomes from the e-learning module, 3 assessed learning outcomes from the guest lectures, and 7 assessed learning outcomes from the business competition. An additional 12 questions asked students about the importance of these 3 business modules to each other, to the students' future careers, and to their desire to become an entrepreneur. The remaining 4 questions asked students to rate the role that these entrepreneurship modules played in ABET student outcomes 3 and 4 [7].

The average ratings for the first 15 questions, which asked students to assess themselves on the learning outcomes of the three business modules, are shown below in Table 1. Questions 1-5 are related to the e-learning module and associated in-class contextual activities in which students developed an elevator pitch. These questions are based directly on learning outcomes developed by KEEN for this e-learning module. Questions 6-8 are associated with the guest lectures that focused on finding gaps in the market and developing a financial business case. Questions 9-15 focus on the learning outcomes of the business competition. From these ratings, it is clear that the students feel the most confident in their abilities related to the elevator pitch module and least confident with the content in the guest lecture module. In looking at individual learning outcomes, the students feel the least confident with the financially-based outcomes and the most confident with those that deal with orally presenting an argument. This seems to make sense in the context of the mechanical engineering curriculum, where students are asked to make presentations more frequently than they are asked to generate financial models.

Table 1: Average student self-assessments of business module learning outcomes

#	Question	Average Response
1	I can make an argument for an urgent need or demand for a product.	4.07
2	I can provide a non-technical explanation of the solutions.	4.39
3	I can clearly state a value proposition.	4.04
4	I can provide a clear path to move forward.	4.28
5	I can implement strategies for recovering from an unsuccessful pitch.	4.00
6	I can analyze gaps in the current market to find where customer needs are not being met.	3.81
7	I can generate a financial business case for a production run.	3.40
8	I can analyze the net present value of a production run.	3.40
9	I can analyze the target market and potential for growth.	3.73
10	I can develop a unique business concept.	3.90
11	I can develop a plan to bring a product to market.	3.88
12	I can assess my company's competitive advantages.	4.06
13	I can calculate the break-even point for a business.	3.78
14	I can make a compelling financial case for a business.	3.61
15	I can orally present my ideas clearly and convincingly.	4.07

While the self-assessment ratings presented in Table 1 provide some basis for evaluation, direct student assessment data is preferable. While direct assessment data has not yet been collected for the content presented in the guest lecture or business competition modules, students were directly assessed on the elevator pitches presented at the completion of the e-learning module. Average ratings for each of the five learning outcomes are shown below in Table 2, with a comparison between average self-assessment and direct assessment ratings for each learning outcome. Because student survey responses were anonymous, a direct comparison on a student-by-student basis could not be made, but the average quantities do show very good agreement with each other and this lends some credibility to the student self-assessment ratings presented throughout this paper.

Table 2: Comparison of self-assessment with direct assessment of learning outcomes from e-learning module

#	Learning Outcome	Self Assessment	Direct Assessment
1	Made an argument for exigency	4.07	4.12
2	Provided a non-technical explanation of the solutions	4.39	4.32
3	Clearly stated a value proposition	4.04	4.04
4	Provided a clear path to move forward	4.28	4.24
5	Implemented strategies for recovering from an unsuccessful pitch experience	4.00	3.84

The average ratings for questions 16-23 are shown below in Table 3. These questions asked students to rate the degree to which the elevator pitch and guest lecture modules prepared students for the business competition module and how much each of the three business modules prepared students for their design projects and their future careers. It can be seen that all but one of these ratings is above the neutral response of 3.0, which indicates that students felt that these modules had a positive impact in both the short and long term. The highest ratings came from the importance of developing an elevator pitch, while the lowest ratings, including the only rating among this group below the neutral response, involved participation in the business competition. The higher ratings associated with developing an elevator pitch could again be due to the students' higher level of comfort with oral presentations. The lower ratings associated with the business competition do not reflect the student self-assessment of learning outcomes, and these ratings seem to depend heavily on whether the students advanced past the initial paperwork-only round of the business competition, which will be discussed in more detail below.

Table 3: Average student responses when asked about the importance of business modules to each other and to their future careers

#	Question	Average Response
16	Developing an elevator pitch for class made me more prepared for the business competition.	3.63
17	Developing an elevator pitch for class made me more prepared for my design project.	3.66
18	Developing an elevator pitch for class made me more prepared for my future career.	3.64
19	In-class guest lectures made me more prepared for the business competition.	3.18
20	In-class guest lectures made me more prepared for my design project.	3.39
21	In-class guest lectures made me more prepared for my future career.	3.45
22	Participating in the business competition made me more prepared for my design project.	2.90
23	Participating in the business competition made me more prepared for my future career.	3.04

The average scores for the remaining 8 questions are shown in Table 4. Questions 24-26 ask students to assess how much each of the business modules contributed to their desire to become an entrepreneur and question 31 asked students to assess whether engineering entrepreneurship will be valuable to their future careers. On average students seemed to have neutral interest in becoming an entrepreneur in response to questions 24, 25, and 26, with 20, 22, and 31 of the 67 students responding “disagree” or “strongly disagree” compared to 26, 32, and 24 responses of “agree” or “strongly agree” respectively. Conversely, the average response to question 31 was considerably higher, which indicates that while students in general did not have a strong interest in becoming an entrepreneur, they did believe the lessons on engineering entrepreneurship would have value in their future careers. These results could be influenced by the fact that The Citadel is a senior military college in which approximately 30% of the student body is contracted to join a branch of the military upon graduation. This often has an impact on student career planning and could influence the ways that students envision their interest in alternative career trajectories. That said, the value of entrepreneurial thinking can be realized in a wide range of careers, whether as an entrepreneur or as an employee of a large organization, and the students seem to be able to acknowledge that value.

Table 4: Average student assessment of the importance of business modules to their interest in entrepreneurship and as they related to ABET student outcomes

#	Question	Average Response
24	Developing an elevator pitch for class made me more interested in becoming an entrepreneur.	3.07
25	In-class guest lectures made me more interested in becoming an entrepreneur.	3.09
26	Participating in the business competition made me more interested in becoming an entrepreneur.	2.75
27	Participating in the business competition helped me understand the importance of my professional and ethical responsibilities as an engineer.	3.01
28	Developing an elevator pitch for class helped me craft how to communicate my engineering design effectively.	3.76
29	In-class guest lectures broadened my understanding of the impact of engineering solutions in a global, economic, environmental, and societal context.	3.49
30	Participating in the business competition expanded my knowledge of contemporary issues.	2.97
31	I believe what I have learned about engineering entrepreneurship will be valuable for my future career.	3.72

The average student response to questions 27-30 can also be seen in Table 4. These questions ask students to assess whether these business modules impacted their performance on certain ABET student outcomes. The answers to questions 28 and 29 are generally positive with 68.7% and 61.2% positive responses to the two questions, respectively. As discussed above with questions related to participation in the business competition, question 27 is influenced by student achievement in the competition. Question 30, while related to the business competition, does not show the same disparity in responses. This question could have low responses simply because of poor alignment between the ABET outcome and the learning activities in this module. While portions of the business competition were open to the public, many student teams did not attend the oral presentations of other teams and thus were not exposed to the problems they were attempting to address or to the questions and concerns of the judges, which could have informed their views of this ABET outcome.

As discussed above, many of the student ratings on questions involving the business competition appear to depend on the level of student involvement in the competition. In order to quantify this difference, student responses were grouped into those that made it past the initial round of the competition (n=32) and those that did not (n=35). To compare these two groups, a two-sample t-test was used to compare the mean responses of each group for each question. The results of this analysis are shown in Table 5, which includes all questions for which the difference between means was significant to a significance level of $\alpha=0.05$. From these results, questions 22, 23, 26, and 27 asked about participating in the business competition. Because the initial round of the

competition was a short written submission without direct feedback, these students may have felt as though they did not participate in the competition in a significant way and therefore it did not have an impact on their future careers or thought processes. Those that did make it past the initial written submission round into the semifinal round of the business competition were tasked with preparing and presenting an elevator pitch to a panel of judges. This additional experience in which the students gained feedback on their elevator pitches and business ideas in general appears to have given students a significant benefit over those that did not progress through the initial round. These benefits are apparent in the students' views of the impact that this experience had on their design projects, future careers, and interest in becoming an entrepreneur.

Table 5: Comparison of student scores between those that made it past the initial round of the business competition and those that did not and the associated p-value from a two-sample t-test

#	Question	Made semifinals	Out in 1st round	p-value
2	I can provide a non-technical explanation of the solutions.	4.56	4.28	0.040
6	I can analyze gaps in the current market to find where customer needs are not being met.	4.06	3.59	0.032
16	Developing an elevator pitch for class made me more prepared for the business competition.	4.09	3.17	0.001
17	Developing an elevator pitch for class made me more prepared for my design project.	3.97	3.34	0.026
22	Participating in the business competition made me more prepared for my design project.	3.28	2.45	0.009
23	Participating in the business competition made me more prepared for my future career.	3.44	2.62	0.009
26	Participating in the business competition made me more interested in becoming an entrepreneur.	3.34	2.03	0.001
27	Participating in the business competition helped me understand the importance of my professional and ethical responsibilities as an engineer.	3.34	2.52	0.036

In addition to positive scores on the four questions discussed above, the experience of preparing for this extra exercise in the business competition semifinals could explain the differences in responses for questions 2, 6, and 16. Questions 2 and 6 are learning outcomes from the elevator pitch e-learning module and the guest lectures, respectively, and question 16 deals directly with the importance of the in-class elevator pitch module to their business competition experience. While causation cannot be determined by this statistical analysis, these results point to an association between better learning outcomes in the supporting modules and success in the business competition.

In an effort to further investigate the link between the three business modules, correlations were performed between the student responses to the learning outcomes from each of the business modules. These correlations between the student responses to learning outcome questions can be seen in Table 6, Table 7, and Table 8. Each of these tables denotes correlations that are statistically significant at a 0.05 level as shaded in green. Table 6 shows the correlation coefficients between the elevator pitch learning outcomes (Q1-Q5) and the guest lecture learning outcomes (Q6-Q8). Table 7 shows the correlation coefficients between the elevator pitch learning outcomes (Q1-Q5) and the business competition learning outcomes (Q9-Q15). Table 8 shows the correlation coefficients between the guest lecture learning outcomes (Q6-Q8) and the business competition learning outcomes (Q9-Q15). Among all of these correlations, only question 2 is not significantly correlated to more than 2 other learning outcomes. The largest correlation coefficients occur between the financially focused learning outcomes from the guest lectures and the varied learning outcomes from the business competition. Among these, only one correlation is not statistically significant. These results indicate a strong interaction between the three business modules implemented in this course. Again, causation cannot be determined from these correlations, but the students with better learning outcome self-assessments in one business module tended to have higher assessments in the others. This could be caused by the synergy of the modules, in that the elevator pitches developed in class and the financial calculations taught during the guest lectures were valuable not only in their own right, but also as supportive material for the business competition. Alternatively, those that had more interest in the content of one module may have simply been primed for interest in the other modules. This explanation is also a positive in that student achievement in one learning module can be extended to a wider variety of learning outcomes by incorporating additional tangentially related modules.

Table 6: Correlation coefficients between learning outcomes from the elevator pitch module and the guest lecture module. Statistically significant correlations are shaded green.

	Q6	Q7	Q8
Q1	0.427	0.282	0.239
Q2	0.278	0.105	0.032
Q3	0.238	0.329	0.337
Q4	0.359	0.528	0.479
Q5	0.441	0.297	0.337

Table 7: Correlation coefficients between learning outcomes from the elevator pitch module and the business competition. Statistically significant correlations are shaded green.

	Q9	Q10	Q11	Q12	Q13	Q14	Q15
Q1	0.123	0.267	0.255	0.334	0.337	0.368	0.330
Q2	0.166	0.139	0.203	0.196	0.079	0.154	0.419
Q3	0.219	0.247	0.232	0.278	0.216	0.217	0.462
Q4	0.425	0.378	0.444	0.405	0.507	0.388	0.319
Q5	0.298	0.311	0.319	0.377	0.363	0.467	0.374

Table 8: Correlation coefficients between learning outcomes from the guest lecture module and the business competition. Statistically significant correlations are shaded green.

	Q9	Q10	Q11	Q12	Q13	Q14	Q15
Q6	0.533	0.508	0.484	0.569	0.511	0.473	0.220
Q7	0.718	0.615	0.622	0.656	0.660	0.600	0.305
Q8	0.799	0.645	0.625	0.720	0.746	0.711	0.339

Conclusions and Future Work

Engineering entrepreneurship modules were incorporated into the mechanical engineering senior capstone course at The Citadel. These modules took the form of 1) an e-learning module focused on developing an elevator pitch, 2) a series of guest lectures dedicated to identifying, justifying, and communicating business decisions, and 3) a business competition in which students brought together the concepts learned in the other business modules to present their senior design projects to a panel of interdisciplinary judges. It was found that there was a significant interaction between these modules, with student survey results revealing not only that students found that the earlier modules were valuable to the business competition, but also that increases in self-reported learning outcomes in one business module were correlated with better self-reported learning outcomes in the others. Students also reported that what they have learned about engineering entrepreneurship and their participation in the business modules have prepared them for their senior design projects and for their future careers, despite neutral interest in actually becoming entrepreneurs. Significant differences were found in both learning outcomes and in perceived value of the business modules between students that made it to the later rounds of the competition and those that did not.

In the future, additional support for developing the financial case for a business will be incorporated, possibly in the form of additional e-learning modules or guest lectures. Because these financially-related learning outcomes received the lowest self-reported scores, this appears to be the area most in need of increased attention. Additionally, the other weak areas in this implementation appear to be the disparity between students with different levels of achievement in the business competition and tepid interest in becoming an entrepreneur. These can both be bolstered with increased guest lectures and participation. The most valuable aspect of participating in the semifinal round of the business competition seems to be the increase in feedback the students receive from the business-focused judges. Bringing business faculty or local small business owners and founders into the senior design class to provide similar insight could provide this value to all of the students rather than just those that progress in the competition. Interest in entrepreneurship could also be increased by increasing student exposure to these actual entrepreneurs. While the current guest lectures exposed students to the entrepreneurial mindset, involving the founders of local startup companies in these guest lectures could lend further credibility to these types of career paths. Because The Citadel is a senior military college, founders of veteran-owned businesses would be of particular interest to those that plan to enter the military upon graduation.

In future implementations of these and other business modules, particular attention will be paid to the timing of content relative to both the other modules and the capstone deliverables in order

to better reinforce concepts across exercises. Additionally, direct assessment is crucial for quantitatively determining the actual impact and effectiveness of each of these exercises and this will be an area to improve upon in future iterations.

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