Student-centered entrepreneurial design education: Course design, development, and assessment

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Introduction

Advancements in engineering education research have led to the development of education programs to equip engineering graduate students with professional skills, in addition to the technical skills they attain through their undergraduate education. Particularly, to enhance the entrepreneurial skills in engineering students, universities are introducing entrepreneurship education (EE) to future engineers [1, 2]. Even though traditionally EE courses were introduced in the management schools, the importance of entrepreneurial skills and capabilities for future engineers has motivated the engineering schools to include them in their curriculum [3]. However, EE courses are offered as electives, limiting the participation of the students [4].

To ensure exposure to broader student groups to EE, this project integrated EE into the first-year engineering graphics curriculum by developing entrepreneurship modules [5, 6]. The engineering graphics course implemented engineering design thinking, where students plan, design, and create a product/service in a real-world context [7]. The course content focused on front-end design processes within design thinking, as the front-end processes offer the greatest potential for changes and improvements because they focus on conceptual development rather than implemented solutions [8, 9]. Effective front-end design practices are critical to product success before the design team decides to pursue manufacturing products. This provided a platform to integrate entrepreneurial modules into the initial stages of the design thinking process. Particularly, using the parallels in the initial stages of the design thinking process, EE modules allowed the students to engage with the stakeholders and then design a solution for their problems [10]. Integrating the entrepreneurship modules equipped students with additional entrepreneurial skills such as opportunity recognition, resource gathering, and planning. Overall, by integrating entrepreneurship education into the first-year design course, the project aimed to enhance entrepreneurial skills among the undergraduate engineering students. The research objective of the project was to determine the impact of entrepreneurial modules in a first-year engineering graphics course on students' entrepreneurial and design self-efficacy, perceived value of engineering, and self-perception of their identity as engineers.

Project Background

This project has been divided into three phases. In the *first* phase, semi-structured interviews were conducted with 16 first-year undergraduate engineering students to understand factors that affected students' motivations towards engineering. The findings revealed four themes that impacted students' motivation: *attention* (creativity, entrepreneurship, and leadership), *relevance* (career relevance, family/community engagement), *confidence* (pre-college background, professional skills, and experience), and *satisfaction* (internal and external satisfaction). The *second* phase was the module development, where modules were designed with a focus on students' motivation. All the modules were designed by a research team, including two faculty members, a graduate student, and an alumnus. The *third* phase involved data collection for the assessment of changes in students' confidence at the beginning and end of the semester. The research question for this phase was: What is the impact of the integration of entrepreneurial modules in a first-year engineering graphics course on students' entrepreneurial and design self-efficacy, perceived value of

engineering, and self-perception of their identity as engineers? Ongoing and future work involves scaling up this project by integrating the modules into more classes.

Course Design Development

The course design development phase was based on Steve Blank's Lean Launch curriculum, which is being widely adopted for engineering students [11]. Literature has noted that the application of Lean Launch in the engineering design courses has developed entrepreneurial skills in engineering students [12]. The first-year engineering graphics curriculum was created to provide students with a platform to develop essential entrepreneurial skills in the engineering profession. The skills, such as planning and identifying a stakeholder, were developed due to the project-based pedagogy of the course. In Lean Launch, instead of using the traditional business plan model, entrepreneurs use models like the business canvas model, empathy maps, value proposition canvas, and stakeholder mapping, as they enable them to receive feedback from stakeholders on their product or service. The *empathy maps* help to understand the user's needs. The *value proposition canvas* tool helps analyze the product's value, and *stakeholder mapping* helps identify all stakeholders affected directly or indirectly by the product. The entrepreneurship design modules were created to provide examples, active learning exercises, and homework that required students to work with stakeholders in their community.

Participants

The developed entrepreneurship modules were implemented in a first-year engineering graphics course offered at a minority serving institution in the United States, with over 40,000 students enrolled in the academic year 2024-2025. Preliminary assessment was collected from engineering students at the beginning of the semester and end of the semester. At the beginning of the semester, 46 students responded to the survey, and 40 students recorded their responses at the end of the semester. For the qualitative assessment, a total of 35 students recorded their responses.

Assessment Methodology

Responses of the survey were used to analyze any statistically significant difference in the mean of the constructs (searching, planning, design, value, and identity) at the beginning and at the end of the semester using a paired t-test. Using ANCOVA, further assessment was performed to evaluate any statistically significant difference in the post-intervention mean of the five constructs (searching, planning, design, value, and identity) across gender and ethnicity, controlling for the pre-intervention mean.

Additional qualitative feedback was gathered using an online tool, Voiceform, to collect audio-based responses from the students. The questions asked the student, "What ways did the course impact your confidence…" for each construct (searching, planning, design, identity, and design). Additional questions were included to understand from the student's perspective "What could have been done in the course to increase your confidence…" for improvement in the course content.

Preliminary Results

Student Projects

The final projects involved the class of 45 students working in groups of five, focusing on identifying potential solutions to the problems they had recognized based on their interactions with stakeholders. The students self-selected projects based on the stakeholders' problems, including but not limited to developing a mobility device for elderly people, and a multipurpose cart for organizing space. The projects were grouped in different categories based on the area of application or industry. For example, the projects that focused on providing solutions for disabled or injured people are grouped under the disabled/injured people, and the projects that are focused on providing solutions for less storage space are categorized in the storage category. The activity of engaging with stakeholders in their environment helped the students reflect on the pains people face in their daily lives. The stakeholders that the students interviewed included their family members, friends, and co-workers. The projects are grouped in Table 1.

Table 1: Details of the Stakeholder Projects

Application of the Project	**About**	**Names of the Project**
Disabled/Injured People	Solutions for the elderly/disabled people, such as rotating shelves in the stores, a motor-driven lever system for injured people.	Redefining mobility; Revolving shelves
Storage	Solutions for small spaces, such as dorm rooms, houses, schools, and universities, where there is very little storage space	Headboard Shelves; LeSquare; Cart
Cleaning	Solutions to clean spaces such as kitchen counters, clogged drains, leaf blowers to reduce the noise pollution	Counter Bot
Sitting Space Solution	Solution for the people who have long sitting hour jobs, and private study places	Study Spaces

Quantitative Assessment Results

A paired t-test was conducted to compare the mean values across the pre-and post-intervention data statistically [13]. Requisite assumptions for the t-test were evaluated [14]. The t-test results indicated a significant difference ($p<0.05$) in the means of the pre- and post-intervention for the constructs of searching ($t(30) = 3.78$, Cohen's $d= 0.68$), planning ($t(30) = 6.53$, Cohen's $d= 1.17$), and design ($t(30) = 5.15$, Cohen's $d= 0.93$) with a small to large effect size, indicating a positive change in students' confidence after they were exposed to the entrepreneurship education modules. However, for the constructs identity($t(30) = 0.00$, Cohen's $d= 0.00$) and value ($t(30) = 0.43$, Cohen's $d= 0.08$), there was no significant difference ($p>0.05$) in the means of the pre- and post-intervention. In other words, there is no change in the value and identity of the students after they were exposed to the entrepreneurship education modules.

A one-factor ANCOVA was calculated to determine if there was a difference in the post-test scores for the constructs (searching, planning, design, identity, and value) across gender and ethnicity. The assumptions of the ANCOVA were evaluated to check the suitability of the data to run the test [15]. The results suggest that there was no significant difference ($p>0.05$) in the post-test when controlling for the pre-intervention. In other words, irrespective of any preliminary knowledge, there was no difference in the confidence of students after the intervention across gender and ethnicity.

Qualitative Assessment Results

The results of the qualitative assessment reveal mixed results. Some students reflected that the entrepreneurship modules helped them to see themselves as engineers; however, students also said that the modules made no impact. Students have highlighted that the activity to interact with stakeholders helped them to reinforce themselves as engineers. Reflecting on this, one of the students responded with,

> *"You know, if you have a question, you calculate the answer. But this class had a whole process. You have a problem? Great. Define that problem. Identify the stakeholder. Make an empathy map of the stakeholder. Identify other stakeholder groups. Identify the consumers. Come up with potential solutions. Come up with a final solution. Refine the final solution until it's perfect. Design it on apps like AutoCAD or SolidWorks. This whole process made me feel more like an engineer than more of my previous classes have done. It definitely showed me the process that engineers go through in their day-to-day life."*

Students' feedback provided an insight into the non-significant results of the quantitative analysis for the value and identity constructs as well. Students' feedback indicated that they understand the value of an engineering degree, which is why they enrolled in it. One of the students responded, *"The course didn't really increase my perceived value of an engineering degree, because I already understood that an engineering degree would be extremely valuable."*

For the identity construct, some students suggested that they don't have enough opportunity to share their work with their family or friends, and hence, their peers and family have no idea what they are doing in the class. On this, one of the students responded with,

> *[…] If the course included more opportunities for students to present their work to a broader audience, like family members or industry professionals, it could give others a clearer understanding of my capabilities in the real-world applications of engineering.*"

Ongoing And Future Work

Quantitative assessment findings from the course design development phase revealed a significant difference in the pre- and post-intervention means of the searching, planning, and design constructs. For the identity and value constructs, there was no significant difference in the students' confidence in their perception of the value of the engineering degree and self-perception of their identity as an engineer after attending the course. The qualitative assessment of student reflections clarified why the identity and value constructs might not be significant in the quantitative

assessment. Accordingly, modifications were incorporated into the subsequent iteration before further implementation.

In the upcoming iterations, the presented project has addressed the feedback by revising the modules to incorporate activities that allow students to receive feedback from stakeholders whom they initially visited and to communicate with their peers. Specifically, an additional activity has been introduced that requires students to present their work to their family and friends, allowing them to showcase their work and receive feedback. Additionally, we plan to expand this project by recruiting new faculty members to introduce the entrepreneurship modules to a larger group of first-year engineering students and perform subsequent assessment. For future projects, it is suggested to expand EE to upper-division courses so that the students are also engaged in product realization. As the EE modules expand to upper-division courses, the students' would have gathered the technical design and manufacturing skills and would thus be able to apply them in the context of EE design to understand and test viable product designs and the product-market fit.

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