Assessing the Development of Student Outcomes in Project-based Learning Engineering Design and Entrepreneurship Courses

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***Abstract*— This work-in-progress research paper focusses on comparing changes in students' learning outcomes in engineering design and entrepreneurship courses. Recent national calls to reform undergraduate engineering education has led to extensive research in the identification and development of effective instructional strategies. Project-based learning (PBL) is one instructional strategy that has received empirical and anecdotal support for its ability to instill professional skills in addition to technical content knowledge in engineering graduates. Engineering programs have increasingly adopted PBL in the form of capstone engineering design courses, entrepreneurship courses, and co-curricular experiences. However, PBL is broadly defined in the literature, and as such, these adaptations are often nuanced in their design, structure, and pedagogical approaches; and consequently, may have differing impact on student learning outcomes.**

Engineering design and entrepreneurship courses are two commonly used avenues in which engineering students are exposed to PBL. In design courses, students often work in teams to complete tasks that lead to devising an engineering solution to a given 'real-world' problem. Most, if not all, engineering students gain exposure to PBL via capstone design courses that are often required in the engineering curriculum. In addition to design courses, entrepreneurship courses also expose engineering students to PBL by engaging them in entrepreneurial projects in which students work in teams, often conceptualizing and designing products. While the engineering design process is more focused on the outcome solution to the problem, entrepreneurship design processes tend to emphasize the front end of the design process, specifically opportunity identification and validation. Students engage in customer discovery and develop prototype solutions. Although nuanced, we hypothesize that due to these different approaches, engineering design and entrepreneurship will have varied impact on student learning outcomes. In our presented work, we investigate these differences by examining changes in students' perceived risk-taking abilities, creative self-efficacy, and entrepreneurial self-efficacy in engineering design and entrepreneurship practicum courses. Preliminary results show that entrepreneurial self-efficacy increases in both design and entrepreneurship courses. However, differences in the magnitude of change for its subconstructs are noted between the two courses. In contrast, increase in risk-taking and creative self-efficacy is only found in the entrepreneurship course and not in the engineering design course. Future work will focus on analyzing the pre-post survey data for statistically significant changes.

Keywords*— *entrepreneurship education, engineering design education, learning outcomes, risk-taking, creative self-efficacy, entrepreneurial self-efficacy, assessment

I. Background

To better ensure alignment between student learning outcomes and performance characteristics needed in future engineers, emphasis has been placed on reforming undergraduate engineering education [1]. In addition to possessing technical knowledge and skills, engineering graduates must possess additional skills such as intercultural intelligence, communication, and self-agency for success and valuable contributions in the workplace [1], [2]. Undergraduate engineering education has been working to instill these skills in students through recommended practices such as project-based learning.

Project-based learning is broadly defined and includes educational activities such as capstone engineering design courses, entrepreneurship courses, and co-curricular experiences. Each of these educational activities has unique design, structure, and student outcomes and experiences. While research exists that investigates these activities [3], differences in the design, structure, and student outcomes have received little focus [4]. Research examining potential shared learning outcomes for these different pedagogical approaches is particularly limited. This ongoing study focusses on examining the differences in learning outcomes between engineering design and entrepreneurship courses.

Design courses are common project-based learning opportunities in engineering curriculum. Teams of engineering students work together to "carry out one or more tasks that lead to the production of a final product - a design, a model, a device or a computer simulation" [5]. Most, if not all, ABET accredited engineering programs require at least one capstone design course. In addition to engineering design courses, entrepreneurship courses have emerged to enhance engineers' educational experiences [6]. Entrepreneurship courses are similar to engineering design courses in that students work in teams, often conceptualizing and designing products [7]. While the engineering design process is more focused on the

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solution to the problem as an outcome, entrepreneurship design processes tend to emphasize the front end of the design process, specifically opportunity identification and validation. Students engage in customer discovery and develop prototype solutions [8]–[10]. Recent work has underscored the overlap between engineering design and entrepreneurship courses [11]. As a result of this overlap, there are several potential shared learning outcomes between entrepreneurship and design courses suggested in the literature. While we acknowledge that other potential shared learning outcomes may exist, our work is focused on three outcomes noted in the literature – *Creative Self-Efficacy*, *Risk-Taking* and *Entrepreneurial Self-Efficacy (ESE)*. Creative self-efficacy assesses one's ability to demonstrate creativity. Creativity is an integral part of entrepreneurship [12] and an important outcome of entrepreneurship education [13]. Creativity is also notably targeted in engineering design education [14]. Similarly, risk-taking abilities is another outcome sought in entrepreneurship courses due to its potential impact on entrepreneurial success [7], [15], and is noted for fostering creativity in the design process [16]. Lastly, entrepreneurial self-efficacy (ESE) is also a potential shared learning outcome emerging due to the overlap of pedagogical approaches used in design and entrepreneurship courses. While ESE is specific to entrepreneurship as it assesses confidence in performing various entrepreneurial tasks, it is also applicable to design education because several entrepreneurial tasks (e.g. needs identification, planning, collaboration and iteration) are also frequently performed in design projects [17], [18].

II. Methods

The participants of this study were students enrolled in two undergraduate courses at a large R1 institution in the Fall/Winter 2017. The first course was a Biomedical Engineering (BME) capstone design course required for graduating seniors in BME. The course utilized project-based learning to expose students to medical device design and learn about the commercialization process. Students worked in teams to develop a functioning prototype aimed at solving a problem provided to them by healthcare professionals. Students were provided guidance in the process of design (i.e. problem definition, concept generation, down selection, design, fabrication, and validation testing) and aspects of the commercialization process (e.g. intellectual property and federal drug administration approval). The second course was an elective entrepreneurship practicum course offered through the College of Engineering. The course followed a project-based learning approach to expose students to real-world entrepreneurial experiences. Students worked in teams on three venture projects. These projects exposed students to various entrepreneurship-related concepts such as business models, problem identification, value proposition, pivoting (a commonly used term referring to a change in business strategy), and customer discovery [19].

A web-based pre and post-survey was administered in the two courses during the first and last weeks of the semester respectively. Three validated instruments used in the survey assessed - entrepreneurial self-efficacy [20], risk-taking [21], and creative self-efficacy [22]. Specifically, eight items from the Creative Self-Efficacy [22] were adapted to measure creative self-efficacy and six items from Meertens's scale measuring perceived propensity to take risks [23]. For the Entrepreneurial Self-Efficacy survey, five more-specific sub-constructs were measured: Searching, Marshaling, Planning, Implementing People, and Implementing Finance [20]. In this survey, Searching refers to an individual's ability to identify opportunities. Marshaling refers to an individual's ability to gather resources to implement a business plan. Planning measures an individual's ability to create the business plan in need of resources, and the Implementing sections of the survey measure an individual's ability to manage the personnel and financial resources collected in the Marshaling phase. In the entrepreneurship course, 49 of 83 students across three sections responded to both pre- and post-surveys giving a response rate of 59%. Of the 49 respondents, 43 responded to all the survey questions giving us a sample of 43 for analysis. The design course had slightly smaller enrollments with 44 students enrolled and 36 who responded to both surveys giving a response rate of 82%. Of those 36 students, 32 responded to all the questions giving us a sample of 32 students for the design course and 75 students overall for analysis.

III. Preliminary Results

Overall, positive changes were noted in the post-survey responses for entrepreneurial self-efficacy in both the entrepreneurship and engineering design courses. In the entrepreneurship practicum course, we noted score increases in each of the five sub-constructs of entrepreneurial self-efficacy (Fig. 1). The highest increase was found in Implementing Finance with an improvement of 0.66. Other sub-constructs with similar gains were Planning and Searching with improvements of 0.60 and 0.54 respectively. Comparatively lower gains were noted Marshaling and Implementing People with increases amounting to 0.37 and 0.24 respectively.

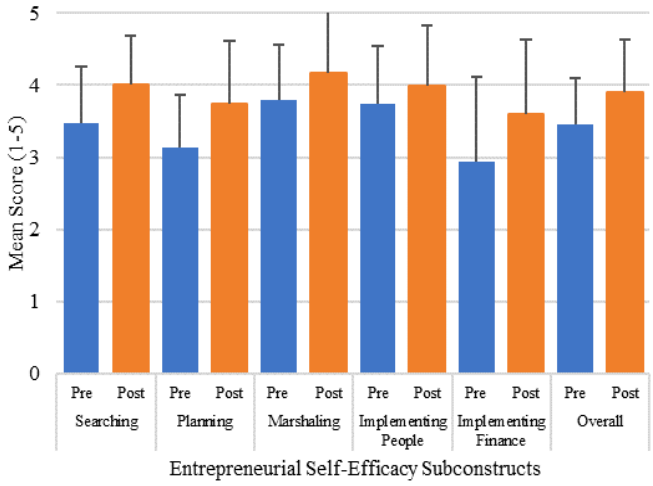

Fig. 1. Mean Pre-Survey and Post-Survey Scores Results for Entrepreneurship Practicum Course in Entrepreneurial Self-Efficacy

In the design course, we also observed score increases across the board for the five entrepreneurial self-efficacy constructs. However, the increases in post-survey scores were much smaller when compared to the entrepreneurship course for each of the constructs. Specifically, we found the largest score improvement for Searching at 0.35 which was also near the top of construct improvements in the entrepreneurship course. We saw an improvement of 0.20 or less in the remaining constructs showed (Fig. 2).

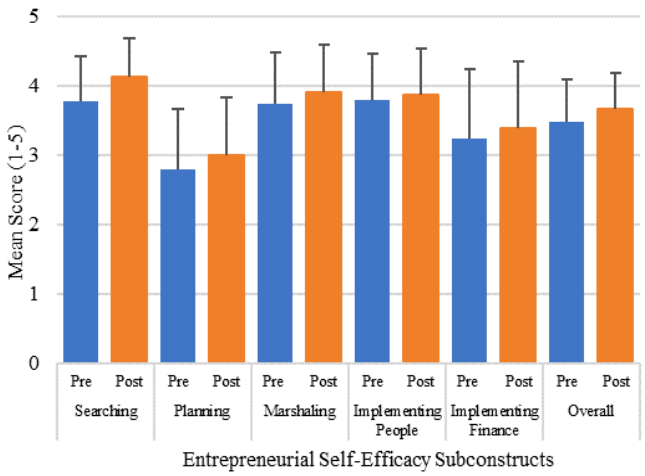

Fig. 2. Mean Pre-Survey and Post-Survey Scores Results for Biomedical Engineering Design Course in Entrepreneurial Self-Efficacy Construct

Regarding students' perceived creative self-efficacy, increases in post-survey scores was noted only in the entrepreneurship course and not in the design course (Fig. 3). Particularly, in the entrepreneurship course, we found a small increase of 0.36 in creative self-efficacy. In contrast, the post minus pre-survey score change in the design course was very minimal with a decrease of 0.03.

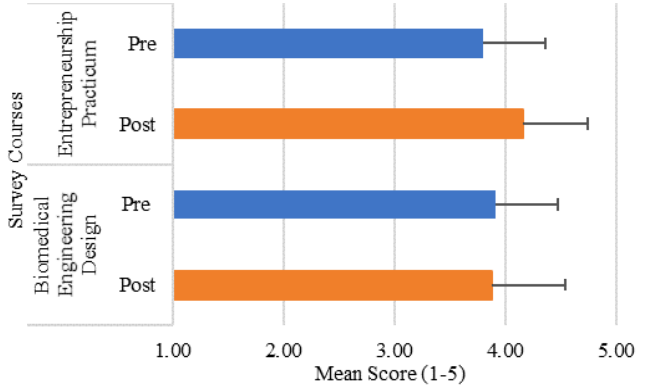

Fig. 3. Mean Pre-Survey and Post-Survey Scores Results for Creative Self-Efficacy in Biomedical Engineering Design and Entrepreneurship Practicum Courses

Lastly, in the case of students' perceived risk-taking abilities, the changes between students pre and post survey responses were very small in both the entrepreneurship and design courses (Fig. 4). In the entrepreneurship course, a small increase of 0.08 was noted in the post responses when compared to the pre-survey responses. In the design course, the post minus pre-survey score change was smaller with a decrease of 0.03 in the post-survey response from the pre-survey response.

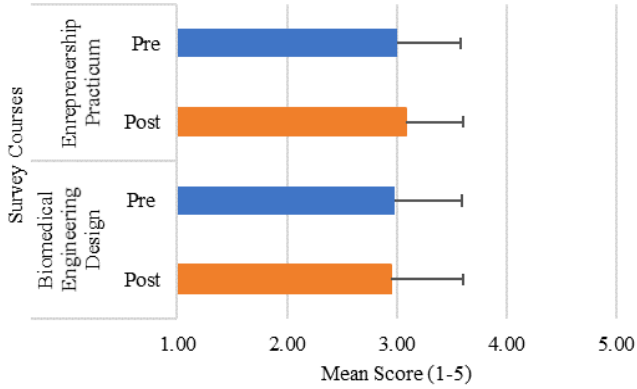

Fig. 4. Mean Pre-Survey and Post-Survey Scores Results for Perceived Risk-Taking Ability in Biomedical Engineering Design and Entrepreneurship Practicum Courses

IV. Implications and Continuing Work

Calls for higher education reform and the use of evidence-based teaching practices have resulted in the creation of a significant number of 'active learning' courses for engineering students. Students are increasingly participating in more and more courses designed to 'engage' the student through team-based projects, open-ended projects, and flipped classroom outside assignments. While these pedagogies are well researched and are shown to be effective for student learning, most of these practices have been studied with respect to traditional lecturing and minimal work has been done to examine differences among them. As faculty look to integrate more of these practices into the curriculum, it is critical that we understand the effectiveness of these practices in impacting student learning. Our presented work is an exploratory attempt to deconstruct specific aspects of engaged teaching practices by examining their impact on potential shared learning outcomes in the case of engineering design and entrepreneurship courses.

Implementation of engineering design and entrepreneurship courses, well known for employing project-based learning (PBL), is steadily increasing in engineering schools. Our findings highlight that not all PBL approaches lead to same outcomes. In fact, our findings suggest that the impact of PBL on student learning depends on the way PBL is implemented and disciplinary context. Our preliminary findings show that entrepreneurship and design courses impact students' perceived risk-taking abilities, creative self-efficacy, and

entrepreneurial self-efficacy differently. We encourage the research community to explore other outcomes that may overlap between the two PBL approaches. In the next steps of this work, we will examine the student data to study statistically significant differences between the pre and post-survey responses for entrepreneurship and design courses. We will also compare score improvements (post - pre) between the courses.

By analyzing the learning outcomes results of this study, we will develop an understanding of pedagogical and curricular factors that contribute to differing impacts on student learning. These results will add to the body of literature on student-centered learning and contribute towards identifying best practices for integrating entrepreneurship training in engineering design education, which has been increasingly receiving advocacy in engineering education community.

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