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Examining Project Based Entrepreneurship and Engineering Design Course Professional Skills Outcomes*

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Design and entrepreneurship education have emerged as platforms for exposing students to 'real-world' project experiences, instilling skills to succeed in the professional market. Both entrepreneurship and design education share similar project-based, active learning pedagogies and claim to cultivate similar 21st century professional skills; however, minimal work has been conducted examining specific student professional outcomes in both entrepreneurship and design courses. Using pre-post survey data, our study explores the impact of two classes, entrepreneurship and biomedical engineering (BME) design, on students' perceived learning gains in three professional skills: Risk-Taking, Creative Self-Efficacy and Entrepreneurial Self-Efficacy (ESE). Results indicated that Entrepreneurship course students reported significant increases in Creative Self-Efficacy and ESE. BME design course students reported minor improvement in certain aspects of ESE. Neither course significantly impacted students' perceived Risk-Taking ability. These results indicate that while design and entrepreneurship courses share content and pedagogy, they have a differing impact on students' perceived skills. We explicate key differences between the courses and their impact on perceived professional skills, examining why design and entrepreneurship education may be unique and how students may benefit from both.

Keywords: design; entrepreneurship; risk-taking; creativity; self-efficacy; outcomes

1. Introduction

In an increasingly global economy where interdisciplinary collaboration, technology-driven markets, and innovation are flourishing, engineering education is facing the need for a shift in focus related to professional skills for graduates to enter the profession [1–3]. Goals for emerging engineering curriculum and pedagogical reforms include instilling a fundamental knowledge of a variety of engineering disciplines, professional skills to address 'real-world' problems, communication and management skills, and an understanding of the ethical implications of technology on society [4]. Among these reforms, organizations are describing a need for engineers who creatively solve 'real-world' problems and can approach problems through an entrepreneurial lens [2, 5, 6]. Including additional professional skills in engineering curriculum without disrupting the standard of four years to complete a degree, requires changes in how engineering is taught [7, 8].

Two major innovations in engineering education have emerged to address these needs: entrepreneurship and design. Entrepreneurship in engineering, a rising opportunity for engineers, seeks to develop creativity, innovation, and other professional skills in engineers to supplement their technical skills upon graduation [9]. Engineering design education, seeks to cultivate professional practice design competencies of engineering graduates [10], including user-centered design and creativity, in engineering fields [11]. Both entrepreneurship and design education incorporate similar learning strategies, such as project-based learning applied to real-life problems [12–14] and claim to meet similar learning outcomes related to professional skills [15, 16].

Traditionally, entrepreneurship and design education in engineering are treated as two independent curricular pathways, leaving students to self-select entrepreneurship education engagement despite the already minimal free electives available to them [8]. While there has been a growing effort to incorporate entrepreneurship education in the context of design [14, 17, 18], little research has been done to explore how entrepreneurship and design education impact professional skill development similarly or differently. The purpose of this paper is to examine the perceived development of two key professional skills, which consistently overlap in the entrepreneurship and design literature, Risk Taking and Creative Self-Efficacy, in the unique context of one entrepreneurship and one design course at one institution, explicating possible pedagogical differences and recommending future work. We also chose to examine Entrepreneurial Self-Efficacy (ESE) as measured by McGee [19], given the fact that McGee's five ESE constructs are consistent with several aspects of the engineering design education studied in this paper. By examining these three self-reported professional skills, we aim to answer the question: Do entrepreneurship and design stu-

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dents perceive an increase in creativity, risk-taking, and entrepreneurial self-efficacy in these specific contexts?

2. Background

2.1 Call for engineering education reform

Over the last 15 years, there have been several calls for engineering education reform around the globe. Recognizing the role engineers play in innovation and as a result, economic growth, there have been several initiatives identifying global challenges and the different skillsets tomorrow's engineers will need to solve these problems [2, 3, 20]. To better prepare engineering graduates, accreditation bodies and international organizations around the world have called for several professional skill outcomes to be added to the technical skills of future engineers [2, 21]. For example, UNESCO in 2010, called for the need to 'more effectively innovate and apply engineering and technology to global issues.' Meanwhile, The World Federation of Engineering Organizations Committee on Education and Training (WFEO-CET) consistently describe future engineers as individuals who can work on worldwide projects, summarizing a number of articles mentioning characteristics such as creativity, endurance to see a project through, and an entrepreneurial mindset, among others [5, 6].

In an effort to address these needs, higher educational institutions have had to reconsider how they are engaging and educating future engineers, keeping up with the standard of four years to complete a bachelor's degree [7, 8]. Furthermore, the inclusion of these outcomes into accreditation outcomes has accentuated reform efforts to cultivate engineering students as professionals equipped with the desired skills to work effectively in their future careers. To address these new outcomes and the need to produce innovative engineers, engineering schools have been developing different means of cultivating some of these skills, two of which include entrepreneurship and engineering design education [22]. While both approaches target development of professional skills in students in their own unique ways, they overlap in their pedagogical and curricular emphasis, leaving students to choose where to engage in a discipline with limited space for electives [8]. Specifically, they both leverage project-based learning, engaging students in the process of identifying a problem to the creating a solution, offering the opportunity to examine clarifying questions: What are the distinctive features of these educational practices that influence students differently or similarly? Are student development needs met with design or entrepreneurship education or are there distinct gains from the different approaches? Our work begins to unpack these questions and focuses on building an understanding of the pedagogical commonalities and differences of these two approaches from a perceived professional skills standpoint.

2.2 Engineering entrepreneurship education

Engineering entrepreneurship education is a recent approach [23] colleges and universities have been using to cultivate innovative and entrepreneurial engineering graduates [24]. Initially starting with traditional business school approaches to entrepreneurship, engineering schools have begun to reconceptualize entrepreneurship education in the context of engineering education and practice [25, 26]. Moving beyond the traditional case study approach of teaching business plans and principles, engineering institutions have moved to a more 'front end', action-based learning approach to entrepreneurship, focusing on opportunity identification, design, and customer discovery [23, 27, 28]. These new programs integrate project-based learning, design, creativity and innovation through curricular and co-curricular programming in a business context.

Although still nascent, entrepreneurship in engineering is becoming an increasingly important component of the most competitive engineer's training, focusing not only on content but transformation of mindset as well [23, 26, 29, 30]. While the definition of entrepreneurial mindset is still being debated in the literature and in practice, there are some common characteristics [31]. In the context of engineering, entrepreneurial mindset commonly addresses, creativity [30], innovation [32], risk taking [33], and critical thinking [34].

Given the aforementioned nascence of the field, assessment of the development of entrepreneurship student professional skills, thus verifying efficacy of pedagogical strategies, lags practice [31, 35, 36]. In a review [35] of entrepreneurship assessment practice, the authors found that there is little empirical research in entrepreneurship assessment practice. Additionally, they noted that there are different assessment practices and cultures between the United States and United Kingdom, resulting in different interpretations and uses of assessment practice. The authors [35] not only advocate for more research in entrepreneurship assessment practice but encourage focus on assessment in disciplines beyond business schools. Another review [31] of entrepreneurship assessment literature across business, engineering and education found that engineering entrepreneurship assessment research significantly lagged the business community and there was little cross-fertilization of ideas in assessment across disciplines. A third review [36], this one about entrepreneurship assessment methods specific to engineering education, had limited utility in systematic evaluation of entrepreneurship curriculum and overall instrument quality was limited. Thus, there is a clear need for more systematic evaluation of engineering entrepreneurship professional skills development.

2.3 Engineering design education

Engineering design education is another approach used by colleges and universities to cultivate the development of engineering students. Effective engineering design is critical for improving product quality, costs, production time and more importantly for aligning products with customer needs [37]. The curricular response to the call for design education has taken several forms, from integrative design curriculum [38, 39] to engineering "capstone design courses" [11]. Capstone design courses, typically offered in a student's final year of undergraduate education, present students with real-world, open-ended projects, developed by a faculty member or external sponsor. While implemented differently across institutions, they generally are taught in the context of project-based learning [11, 40]. As design education has evolved, it has grown to include first-year design experiences to expose students to engineering early in the curriculum, while they are completing traditional "engineering science" requirements [11].

The act of design is complex, and has been a growing area of research since World War II [41]. Recently, design research has focused on the concept of design thinking [11]. Design thinking reflects the 'complex processes of inquiry and learning that designers perform in a systems context, making decisions as they proceed, often working collaboratively on teams in a social process, and "speaking" several languages with each other (and to themselves)' [11 p. 105]. Effective design thinking is increasingly becoming associated with creativity and innovation [42, 43]. The complexity of design thinking has resulted in numerous efforts to better understand design with respect to characteristics of design thinkers, differences between novice and expert designers and the process itself [43].

The introduction of design education has also inspired engineering design education research, focusing on several aspects of design including effective pedagogical practices and the development of assessment tools [10]. As a result of the complexity of design thinking, identifying key outcomes and assessing effective measures of design education is still being broadly explored. The primary focus of design education assessment research has been measuring "students' understanding of the design process as well as their skills in executing the process [10]". While design classes are consistently acknowledged for addressing ABET professional outcome criteria [21, 44], there has been less of a focus on how to assess the impact of design education on the development of professional skills, such as innovation and creativity [45], as opposed to assessing resultant student design skills [12, 46, 47].

2.4 Parallels between entrepreneurship and design education

Entrepreneurship and design education share many similarities. 'Solving design problems' in an engineering context involves application of technical knowledge to transform original ideas to practical applications [48 p. 60]. This transformation is achieved through the engineering design process in which designers use design thinking to systematically 'generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints' [11, p. 104]. To develop this design thinking, engineering design courses focus not only on the creation of a physical product but also on taking the intended end user into account in the design process. Similarly, entrepreneurship is described as a complex process that is 'about creating new opportunities and executing in uncertain and even currently unknowable environments' [49 p. 55]. Creating new opportunities in entrepreneurship involves incorporation of end user feedback in various entrepreneurial subprocesses such as customer discovery, needs assessment, pivoting and opportunity identification. Similar to engineering design, the focus on targeted end user/customer is central to the entrepreneurial process.

Both engineering entrepreneurship and design courses follow a similar pedagogical format with emphasis on project-based learning, teamwork and collaboration to expose students to this user-centered approach. As a result, both entrepreneurship and design have received increasing advocacy supporting their potential to attain targeted professional skills in engineers in the literature. For example, a study by Davis and Rose [14] compared a design course's learning outcomes to those of ABET and found that professional skills such as designing and conducting experiments to meet desired needs, analyzing and interpreting data, customer discovery, multidisciplinary teamwork, communication skills, and an understanding of engineering's place in society could be addressed in the design curriculum. Similarly, in a study by Dabbagh and Menace [50], a case was made that the following learning outcomes can be met through entrepreneurial training: designing to meet desired needs, teamwork (particularly multidisciplinary teamwork), communication, problem-solving, and the understanding of engineering practice and its place in society. This work underscores that although entrepreneurship and design education have emerged in silos, they jointly emphasize several skills critical for the development of future engineers.

2.5 Theory and hypotheses

2.5.1 Potentially shared entrepreneurship and design professional skills

The literature offers insights into key outcomes that both engineering design and entrepreneurship courses aim to instill in students. Based on the literature, two professional skills which are likely present in both courses, but are not well-studied, have been chosen for the focus of our study: Risk-Taking, and Creative Self-Efficacy.

In the realm of engineering design, risk-taking is linked with design concept generation and the lack of risk-taking ability has been noted as a hindrance to pursuing creative approaches in engineering design [51]. In the entrepreneurial space, risk-taking is extensively cited as a critical factor for overall entrepreneurial success [52] and particularly as an important outcome of engineering entrepreneurship education [53]. Thus, risk-taking is a potential shared outcome between entrepreneurship and design courses due to its influence on the product innovation process which is a fundamental part of both engineering design and entrepreneurship [54].

Creativity unarguably also remains a key driver for engineering design [55] and entrepreneurship education (Hamidi, Wennberg, & Berglund 2008); and thus one's confidence in their ability to demonstrate creativity (creative self-efficacy) is an important potential shared professional skills outcome. While creativity is an integral component of entrepreneurship [57], it is also noted as a key aspect of engineering design [58]. Unsurprisingly, creativity, often tied to promoting innovation, has been defined in nuanced ways in educational contexts differing in their emphasis on problem-solving and product/process development [59]. For our study, we use a more generic conceptualization of creativity which involves departing from norms to find novel ways of pursuing different tasks by making atypical associations with existing knowledge, using imagination and experimentation [59]. We assess the development of creative self-efficacy or an individual's self-perceived ability to demonstrate creativity.

As discussed earlier, there is notable overlap between entrepreneurship and engineering design education in terms of tasks and processes that students experience. Therefore, unarguably, increasing the confidence in students' ability to perform such tasks is a likely professional skills outcome for both courses. Entrepreneurial Self-Efficacy (ESE), described as one's confidence in his/her ability to perform various entrepreneurship-related tasks (e.g., opportunity identification and iteration), is a widely examined metric in entrepreneurship education [60]. ESE has been used to assess entrepreneurial success [61, 62] and career interests [63]. In engineering, ESE has been often noted as a key outcomes measure for assessing engineering entrepreneurship education efforts [64–66]. In design education, although ESE is not explicitly mentioned as a learning outcome, measures examining students' self-efficacy with respect to performing tasks such as needs identification, iteration, and collaboration have been developed to assess design education [67, 68]. The ESE scale developed by Mcgee, Peterson, Mueller, and Sequeira [60] is particularly useful in measuring ESE in the design context due to its granular insight on ESE related professional skills that can be mapped onto design.

As evidenced by the existing literature, there is a sizable overlap between engineering entrepreneurship and design education in terms of pedagogy, goals, intended learning outcomes, and professional skills. While assessment research exists for the two approaches separately, work focusing on potential shared outcomes (professional skills or learning outcomes) between the engineering entrepreneurship and design education is scarce. This work is important because of the increasing course load needed to prepare engineering students to contribute to the workforce of the future [7, 8]. Our study examines the development of three potential professional skills, opening the opportunity to further examine their shared impacts in future studies. We examine risk-taking, creative self-efficacy, and ESE in entrepreneurship and biomedical engineering design courses. We hypothesize that:

H1: Entrepreneurship courses increase Risk-Taking, Creative Self-Efficacy, and ESE scores in students.

H2: BME Design courses also increase Risk-Taking, Creative Self-Efficacy, and ESE scores in students.

Biomedical engineering (BME) actively combines both engineering design and entrepreneurial professional skills into its curriculum. BME design seeks to incorporate business, entrepreneurship, design regulation, and manufacturing knowledge into the inherently interdisciplinary field of BME [29, 69–71]. Our paper unpacks the similarities and differences between BME design and entrepreneurship approaches to skill development from a perceived professional skills perspective.

3. Methods

Two experiential learning courses taught at a large, Midwest, R1 institution, were analyzed in this study using a pre-survey and post-survey method to measure three self-reported professional skills: Risk-Taking, Creative Self-Efficacy, and ESE. This study design was implemented in to measure students' confidence in and perceived development of the professional skills measured. Using t-tests (both paired and unpaired) with pre-survey and post-survey responses to analyze significant improvement in self-reported data is common practice among social science researchers performing preliminary studies on the effect of a course on attitudes, beliefs, or skills using survey data [72–74].

3.1 Research context

3.1.1 Entrepreneurship practicum course

The Entrepreneurship Practicum course was a one-semester, experiential course offered by the university's College of Engineering. This course was one of several different capstone entrepreneurship practicum courses offered at the university. Briefly, the practicum courses aim to use project-based learning to teach customer discovery and familiarize students with the process of starting a business emphasizing brainstorming, needs finding, value creation, and other entrepreneurial skills. A more detailed description of this course has been previously published [75]. Throughout the semester, students participated in three different team projects, two short projects and one longer final project. The first project exposed students to business models. The second project focused on problem identification and venture creation. For the final project, students were given the freedom to identify a problem to solve and apply skills developed in projects one and two to their own problem. The instructors were responsible for forming teams in the first two projects and students were left to create their own teams for the final project.

While the course is grounded in the College of Engineering, students from across the university were enrolled. As a result, projects were not specific to a discipline and were not specific to engineering technology solutions. The course focused on customer discovery, ideation and venture creation. Given the diversity of projects, industry specific resources (e.g., regulatory processes) were not brought into the daily curriculum.

3.1.2 BME design course

The BME design course was a one-semester senior capstone design course offered yearly. All graduating BME students at this institution are required to take either a one or two semester BME design course. While the content of the one and two semester design courses are similar, students in the two-semester design course have more time to develop and test their prototypes. The BME design course was an experiential learning opportunity for students to practice medical device design and the commercialization process. As a part of this experience, students formed teams, selected a medical problem provided by someone in the healthcare field, and created a functioning prototype to solve the problem. Concurrently, students pursued their development in the context of commercialization, thus they explored potential conflicts in intellectual property and Food and Drug Administration (FDA) processes for approval relative to their designs. Students worked directly with healthcare providers, faculty mentors and industry mentors throughout the semester.

The BME design instructor was responsible for guiding the teaming process. Upon enrollment, students completed a CATME Team Maker survey (www.catme.org). Based on research that identified criteria that are important in student learning, the CATME Team Maker Tool assisted instructors in developing well-balanced teams [76]. Criteria included student schedule, gender, race/ethnicity, grade-point average, software skills, discipline, shop skills etc. Leveraging the Team Maker results, the instructor was able to form nine well-balanced teams of four to five students per team. Within the first week of class, the teams attended a project fair where project sponsors from the healthcare field presented ten different clinical problems. Each team was instructed to rank up to three projects to pursue. Not only were students responsible for ranking the projects, they also had to submit a written request justifying their ranked project preferences. The Instructor used these rankings and justifications to assign teams to projects. Every effort was made to offer students one of their top two choices.

With projects assigned, student teams worked with their project sponsors and faculty mentors to go through the design process: problem definition, ideation and concept generation, down selection, design, fabrication, and validation. Students participated in three design reviews throughout the semester and had opportunities to work with representatives of the intellectual property and FDA communities.

3.2 Participants and procedures

A pre-post survey approach was used in our study to assess the development of the three *dependent vari-*

ables (Risk-Taking, Creative Self-Efficacy, and ESE) and differences after each course (*independent variable*). Students in this study were enrolled in one of two courses taught during the 2016/17 academic year: (1) the undergraduate entrepreneurship practicum course, or (2) the capstone BME design course. Eighty-three (83) students were enrolled in the entrepreneurship practicum course across three sections. Only forty-nine (49) of the 83 entrepreneurship students completed the pre and post surveys. Of those 49 entrepreneurship students, 43 answered all the survey questions allowing for them to be used in the study (28 male, 15 female). The BME design course had a total of 44 students. Of the 36 BME students who responded to the pre and post-surveys, only 32 answered all the questions allowing for them to be used in the study (16 male, 16 female).

We reached an overall sample size of 75 and response rate of 59% by combining the entrepreneurship and design courses. Students included in the survey were approximately 59% male. Approximately 77% of students in both classes were in their third or fourth year of post-secondary education with almost 95% of them between 18 and 22 years of age. Over 50% of students enrolled in either class were in an engineering major with other majors being science, business, social science, arts and humanities, or other. Approximately 45% of students had an entrepreneur in their family, and almost 70% of students had participated in entrepreneurship courses in some capacity before the BME design or entrepreneurship practicum courses (Table 1).

3.3 Measures

The web-based pre- and post-surveys administered in the first and last weeks of the semester assessed our three *dependent variables*—Risk-Taking [77], Creative Self-Efficacy [78] and Entrepreneurial Self-Efficacy [60]. Survey items to measure Risk-Taking [77] and Creative Self-Efficacy [78] used a 5-point Likert-scale (1 = Strongly Disagree 5 = Strongly Agree) (Table 3). Risk-Taking was measured using six items adopted from Meertens & Lion [77]'s Risk Propensity Scale assessing tendency to take risks. While this scale typically consists of seven items, including the seventh item "I take risks with my health" would not have been appropriate for our study examining students' attitudes on their profes-

Table 1. BME capstone design and entrepreneurship practicum student demographics

	Entrepreneurship (n = 43)		BME Design (n = 32)	
Respondents' Profile	**Response Count**	**Frequency (%)**	**Response Count**	**Frequency (%)**
Gender				
male	28	65.1	16	50.0
female	15	34.9	16	50.0
Years of Education Since High School				
2 or less	12	27.9	0	0.0
3	21	48.8	2	6.3
4	8	18.6	27	84.4
over 4 years	1	2.3	3	9.4
no response	1	2.3	0	0.0
Age				
18–20 years	22	51.2	1	3.1
21 years	17	39.5	15	46.9
22 years	4	9.3	12	37.5
23 years and over	0	0.0	4	12.5
Major				
engineering	9	20.9	32	100.0
science	1	2.3	0	0.0
business	2	4.7	0	0.0
social science	15	34.9	0	0.0
arts and humanities	5	11.6	0	0.0
other	11	25.6	0	0.0
Entrepreneur in the Family				
yes	25	58.1	10	31.3
no	15	34.9	22	68.8
not sure	3	7.0	0	0.0
Previous Entrepreneurship Coursework				
yes	40	93.0	12	37.5
no	3	7.0	20	62.5

Table 2. Survey questions to measure Risk-Taking and Creative Self-Efficacy

Creative Self-Efficacy [78] and Risk-Taking [77] Items
Creative Self-Efficacy
1. I will be able to achieve most of the goals that I have set for myself in a creative way.
2. When facing difficult tasks, I am certain that I will accomplish them creatively.
3. In general, I think that I can obtain outcomes that are important to me in a creative way.
4. I believe I can succeed at most any creative endeavor to which I set my mind.
5. I will be able to overcome many challenges creatively.
6. I am confident that I can perform creatively on many different tasks.
7. Compared to other people, I can do most tasks very creatively.
8. Even when things are tough, I can perform quite creatively.
Risk-Taking
1. Safety first*.
2. I prefer to avoid risks*.
3. I take risks regularly.
4. I really dislike not know what is going to happen*.
5. I usually view risks as a challenge.
6. I view myself as a risk-seeker.

Note: * Indicates a question which was reverse coded before data analysis began.

sional skills and tendencies. Thus, we chose to exclude the seventh Risk-Taking item. Creative Self-Efficacy was measured using eight items adopted from creative self-efficacy scale commonly used to measure a student's beliefs in their ability to produce innovative ideas or outcomes.

The Entrepreneurial Self-Efficacy scale developed by McGee et al. (2009) was used to measure Entrepreneurial Self-Efficacy with respect to five subconstructs: *Searching, Marshaling, Planning, Implementing People, and Implementing Finance*. Survey items used a 5-point Likert-scale (1 = Not Confident at All 5 = Very Confident) (Table 2). The *Searching* subconstruct measured an entrepreneur's self-reported ability to identify an opportunity. The *Planning* subconstruct measured self-reported ability to take an opportunity and create a feasible business plan. The *Marshaling* subconstruct measured self-reported ability to gather the resources required to implement the business plan. *Implementing* subconstructs were measured in two parts: *People* and *Finance*. *Implementing* required an entrepreneur to self-report an ability to balance business relationships with employees, customers, suppliers and providers of capital. While we recognize that Entrepreneurial Self- Efficacy construct was developed to measure self-efficacy in the context of entrepreneurship specifically, we argue that it is also applicable in measuring self-efficacy in engineering design as its sub constructs use a more granular approach to capture skills also frequently taught in design courses (e.g., *Searching, Planning, Marshaling*).

Table 3. Survey questions to measure Entrepreneurial Self-Efficacy

Entrepreneurial Self-Efficacy Items [60]
Searching
1. Brainstorm (come up with) a new idea for a product or service.
2. Identify the need for a new product or service.
3. Design a product or service that will satisfy customer needs and wants.
Planning
1. Estimate customer demand for a new product or service.
2. Determine a competitive price for a new product or service.
3. Estimate the amount of start-up funds and working capital necessary to start my business.
4. Design an effective marketing/advertising campaign for a new product or service.
Marshaling
1. Get others to identify with and believe in my vision and plans for a new business.
2. Network—i.e., Make contact with and exchange information with others.
3. Clearly and concisely explain verbally/in writing my business idea in everyday terms.
Implementing People
1. Supervise employees.
2. Recruit and hire employees.
3. Delegate tasks and responsibilities to employees in my business.
4. Deal effectively with day-to-day problems and crises.
5. Inspire, encourage, and motivate my employees.
6. Train employees.
Implementing Finance
1. Organize and maintain the financial records of my business.
2. Manage the financial assets of my business.
3. Read and interpret financial statements.

The use of items derived from pre-established scales strengthened the content and face validity of our study. Our adopted survey items differed from the original survey in the Likert-scale response options (from 5, 6, or 9-point to all 5-point response options) to enhance the readability of the survey for the study participants. Because of our limited sample size, we did not perform factor analysis on the data. However, internal consistency of the used scales was tested. High Cronbach's Alpha values for the assessed constructs and subconstructs demonstrated the internal consistency of the scale items—0.91 (Entrepreneurial Self-Efficacy), 0.76 (*Searching*), 0.77 (*Planning*), 0.77 (*Marshaling*), 0.89 (*Implementing People*), 0.92 (*Implementing Finance*), 0.74 (Risk-Taking), and 0.91 (Creative Self-Efficacy). The representative score for each of the constructs was calculated by averaging the responses to the individual items in each construct.

3.4 Data analysis

Descriptive statistics were generated for pre- and post-survey scores to develop an overall understanding of the score changes in each construct and for each course. Paired average pre- and post-survey scores were determined as well as score changes by taking post-survey minus pre-survey scores. Paired sample t-tests on each of the constructs were then performed, separating the sample (n = 75) into the two courses (H1 and H2): entrepreneurship practicum (n = 43) and BME design (n = 32). Because we performed multiple comparisons using t-tests, we accounted for the possibility of a false-positive by using Bonferroni's correction. For significant p-values, effects sizes were calculated for each construct and course combination (16 total tests) allowing us to make inferences about the effect of the course on these professional skills, and account for the limitations of relying solely on p-values.

4. Results

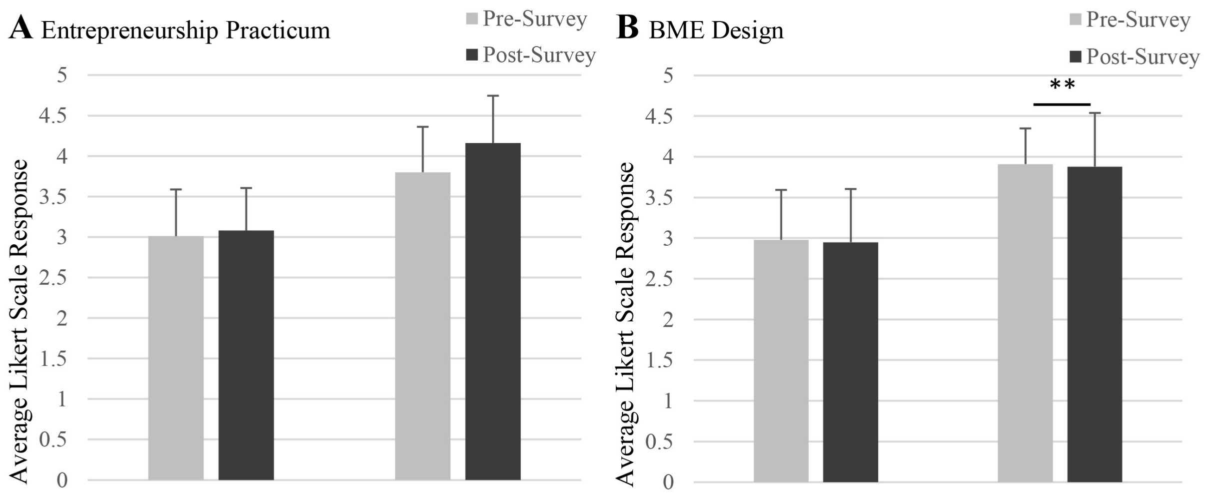
4.1 Descriptive statistics

In looking at the mean scores in the pre-survey, the two constructs of interest in this study, Risk-Taking and Creative Self-Efficacy had differing results between courses (Fig. 1). While students in the two courses began at similar levels, students did not experience similar changes in perceived skill development. In the BME design course there was nearly no change in scores between pre- and post-surveys (Fig. 1) with the largest difference being a decrease in average Creative Self-Efficacy score of 0.04. We observed improved scores in the entrepreneurship practicum course in Creative Self-Efficacy (0.361) while Risk-Taking scores were nearly stagnant across both courses.

We noticed that the entrepreneurship practicum and BME design course started at very similar score levels in all the constructs and separately measured subconstructs of ESE. Both courses, entrepreneurship and BME design, demonstrated increases in all five Entrepreneurial Self-Efficacy subconstructs (Fig. 2). The entrepreneurship practicum course showed improvement in all five subconstructs with the highest improvement in *Implementing Finance* (0.659) and the lowest improvement in *Implementing People* (0.244) (Fig. 2A). The BME design course showed the largest improvements in *Searching* (0.355) and *Planning* (0.195) with smaller increases in the remaining constructs. The average improvement in overall Entrepreneurial Self-Efficacy score for BME was 0.179 (Fig. 2B) while the improvement for entrepreneurship was 0.453 (Fig. 2A). Interestingly, all but the smallest improvement (*Implementing People*) in constructs measured in the entrepreneurship course exceeded the largest improvement in the BME design course.

4.2 Comparison of pre to post change within courses (paired t-tests and effect size)

We used paired t-tests to compare average improve-



A

	Risk-Taking	Creative Self-Efficacy
Mean (Pre)	3.001	3.799
S.D. (Pre)	0.578	0.561
Mean (Post)	3.081	4.160
S.D. (Post)	0.525	0.585
Change	0.080	0.361
p-value	0.1719	0.0001

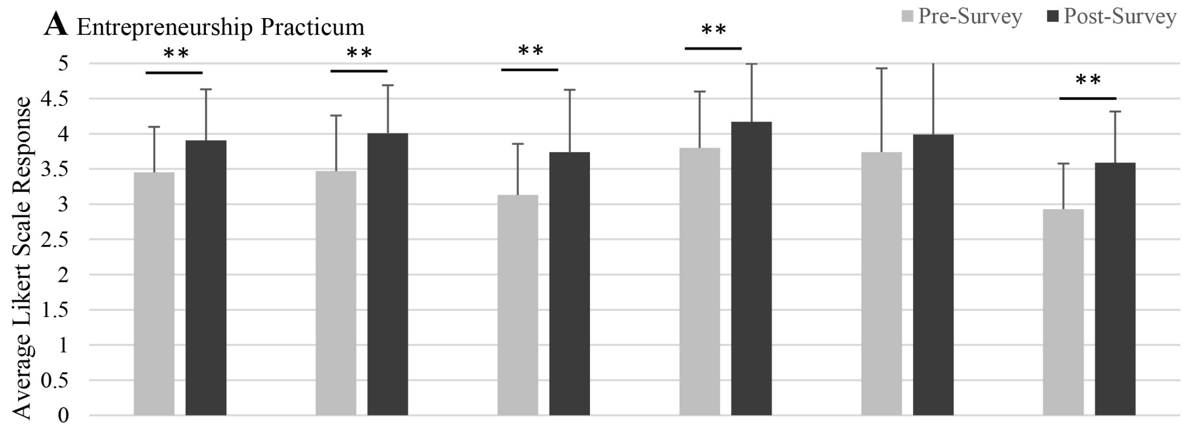
B

	Risk-Taking	Creative Self-Efficacy
Mean (Pre)	2.979	3.910
S.D. (Pre)	0.609	0.559
Mean (Post)	2.948	3.879
S.D. (Post)	0.654	0.659
Change	-0.031	-0.031
p-value	0.3335	0.3429

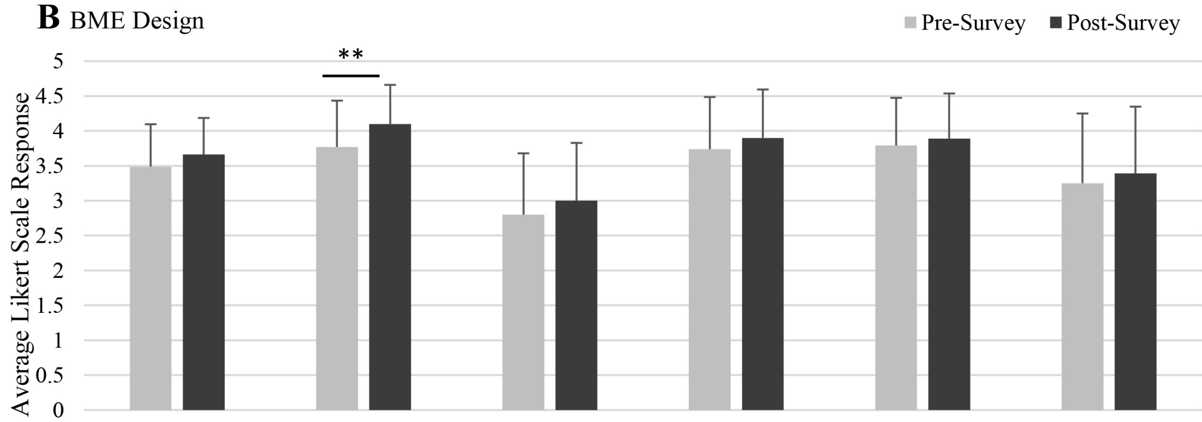
Note: Bonferroni adjusted, significant paired sample t-tests indicated with *p<0.05 (adjusted value 0.003), **p<0.01 (adjusted value 0.0006) A. Entrepreneurship Practicum course n=43 B. BME Capstone Design course results n=32.

Fig. 1. Results of average score for pre- and post-surveys for Risk-Taking and Creative Self-Efficacy.

ment in the entrepreneurship practicum course and in the BME design course for each of the constructs and subconstructs of interest. Using the Bonferroni adjusted p-value cutoffs of 0.003 ($p < 0.05$) and 0.0006 ($p < 0.01$), the BME design course resulted in only one statistically significant increase in self-reported scores: the subconstruct measuring Entrepreneurial Self-Efficacy in Searching (Fig. 2B). The BME design course did not demonstrate significant increases in either Risk-Taking or Creative Self-Efficacy. The entrepreneurship practicum course demonstrated significant increases in four of the five Entrepreneurial Self-Efficacy subconstructs resulting in a significant increase in Overall Self-Efficacy scores. The subconstruct where significant improvements were not demonstrated was Implementing People (Fig. 2A). A significant increase in Creative Self-Efficacy scores was demonstrated in



	Overall Entrepreneurial Self-Efficacy	*Searching*	*Planning*	*Marshaling*	*Implementing People*	*Implementing Finance*
■ Mean	3.452	3.465	3.134	3.798	3.744	2.930
■ S.D.	0.647	0.791	0.727	0.760	0.801	1.192
■ Mean	3.905	4.008	3.738	4.171	3.988	3.589
■ S.D.	0.727	0.680	0.885	0.883	0.826	1.036
Change	0.453	0.543	0.605	0.372	0.244	0.659



	Overall Entrepreneurial Self-Efficacy	*Searching*	*Planning*	*Marshaling*	*Implementing People*	*Implementing Finance*
■ Mean	3.487	3.770	2.805	3.740	3.792	3.250
■ S.D.	0.609	0.664	0.879	0.746	0.684	1.009
■ Mean	3.661	4.125	3.000	3.906	3.885	3.385
■ S.D.	0.525	0.560	0.828	0.694	0.647	0.958
Change	0.174	0.355	0.195	0.166	0.093	0.135

Note: Bonferroni adjusted, significant paired sample t-tests indicated with *p<0.05 (adjusted value 0.003), **p<0.01 (adjusted value 0.0006) A. Entrepreneurship Practicum course results n=43 B. BME Design course results n=32.

Fig. 2. Results of average score for pre- and post-surveys for Entrepreneurial Self-Efficacy.

Table 4. P-value and effect size calculations for BME Design and Entrepreneurship Capstone course paired t-tests

	Entrepreneurship (n = 43)		**BME Design (n = 32)**	
Construct	**p-value significance**	**Cohen's D effect size**	**p-value significance**	**Cohen's D effect size**
Entrepreneurial Self-Efficacy	**0.0003	0.76	0.0263	–
Searching	**0.0002	0.59	**0.0004	0.66
Planning	**0.0001	0.62	0.0944	–
Marshaling	**0.0004	0.55	0.0290	–
Implementing People	0.0047	–	0.1814	–
Implementing Finance	**0.0003	0.57	0.2025	–
Creative Self–Efficacy	**0.0001	0.15	0.3429	–
Risk Taking	0.1719	–	0.3335	–

Note: Bonferroni adjusted, significant paired sample t–tests indicated with * $p < 0.05$ (adjusted value 0.003), ** $p < 0.01$ (adjusted value 0.0006). Effect sizes calculated for statistically significant results only.

the entrepreneurship course as well (Fig. 1B); however, no significant increase in Risk-Taking was demonstrated. For each of the significant increases, an effect size was calculated and a moderate effect size between 0.5 and 0.8 was found for all significant results (Table 4).

5. Discussion

Fueled by the need to prepare engineering graduates to meet the demands of a competitive global economy, several pedagogical reforms have been initiated by colleges and universities. Our work focuses on entrepreneurship and design education, which has recently gained significant traction in the research and practitioner community. As a result, a wide variety of approaches have been implemented in undergraduate courses to attain the targeted skills. These differing experiences are likely to lead to variation in students' self-reported professional skills. As reflected in our findings, several similarities and differences in assessed professional skills were noted between the entrepreneurship practicum and BME design courses.

In our study, we found that the students reported an increase in creative self-efficacy in the entrepreneurship practicum course and not in BME design course. One explanation is due to differences in the emphasis between the two courses. In the entrepreneurship practicum course, the students have more autonomy to identify potential problems and ideate solutions for those problems. Students are not bound by any technical constraints and can devise any type of solution they deem will best solve the problems. In contrast, the BME design course offers a more constrained environment for students to develop solutions to the assigned problems. In addition to regulatory and physiological constraints, students are also bound to the resources provided to them and the financial constraints set by their project sponsors (clinical/healthcare providers in this case). This format is typical of design courses in engineering. Engineering capstone design projects get their project assignments primarily from industry sponsors [79]. While sponsorship is beneficial from an administrative perspective, it may place some restrictions on students when pursuing solutions. Thus, to foster creativity, design courses should examine how experiences can be developed that pose less constraints on students and provide avenues for creative pursuance of ideas. Also, it is important to note that design courses do not always spend significant amount of time engaging students' in the idea generation process. In contrast with entrepreneurship courses, the design courses primarily focus on devising a solution to the problem and not idea generation. This is another aspect that may cause hindrance in the development of students' creativity skills in design courses. Future research should focus on identifying best practices for developing design courses that offer the right balance of student autonomy, idea generation, sponsor constraint and instructional direction.

Another key difference between the two courses is the emphasis on business model development. Similar to typical design courses, the BME design course placed more emphasis on finding a technological solution to the problem rather than developing a product to meet the market need. On the other hand, in entrepreneurship courses, a business model is proactively developed to incorporate business-related aspects in the design process. Consequently, we noted differences in student outcomes pertaining to ability to perform business planning tasks (*Planning*) and managing financial aspects (*Implementing Finance*). For both these professional skills, statistically significant increases were noted only in the entrepreneurship practicum course and not in the BME design course.

While these findings highlight key areas of difference in the design course, our results also show that the design course was able to achieve similar increase in Entrepreneurial Self-Efficacy pertaining to *Searching* subconstruct as students in the entrepreneurship practicum course. These findings reiterate that design courses are a potential platform to instill some of the entrepreneurial skills in students. Particularly, the ability to identify an opportunity is one skillset that can be developed through both design and entrepreneurship courses. *Searching* for an opportunity is the most fundamental step in the entrepreneurial process. In entrepreneurship courses, students are actively engaged in opportunity identification which involves gathering information from a potential customer segment about their user needs and requirements. Similarly, engineering design courses are increasingly moving to the human-centered design approach which involves stakeholder identification and gathering user requirements to identify opportunities to be addressed through engineering product design [80]. This implies that skill development in the area of opportunity identification or the searching aspect of ESE are as inherent to engineering design courses as they are for entrepreneurship courses. Thus, engineering design courses would benefit if other aspects of entrepreneurship education were incorporated in it. Considering the large number of required courses engineering students have to complete to meet degree requirements, this integration of entrepreneurship with design courses is one way these skills can be taught to engineering undergraduates [17, 81–83].

Intriguingly, we found no statistically significant change in students' risk-taking ability in both the entrepreneurship practicum and BME design courses. In both the courses, students' success in their projects is dependent on the evaluation by the courses' instructional team. Also, exposure to real-world market comes primarily in the form of design reviews for BME students in which students present their progress to a panel of industry experts and seek feedback on different aspects of the designed product. Market exposure is similarly low stakes in entrepreneurship courses. As a result of students' limited exposure to high-risk situations, these courses might not lead to attainment of risk-taking abilities in students, as reflected in our findings. One way of attaining these outcomes might be through pitch competitions in which students present their work for monetary support to pursue their work beyond the course [82, 84, 85]. Another approach could be creating an 'artificial economy' in which the real world market environment is simulated within the course [86]. While these approaches offer plausible solutions, a broader question warranting further examination is the testing of the efficacy of the anecdotally recommended approaches. Future work should focus more on examining risk-taking as a learning outcome across different curricular and pedagogical approaches used in entrepreneurship and design education to identify best practices.

Lastly, in both the courses, we found no significant change in students' confidence in their ability to manage people-related aspects of a venture (*implementing people*). As with the rest of our findings, since our study was limited to two courses, this finding cannot be used to make generalizable claims. Nonetheless, it points out that managing people aspect of entrepreneurship and design education that needs further research and theoretical attention. Although both approaches offer students a team-based learning environment, limited work has been done to examine how these approaches assist in developing managing people-related skills in students. Future work should focus on unpacking the team-based learning environments in engineering entrepreneurship and design courses in light of development of skills pertaining to managing people in a team or a business.

5.1 Limitations and future directions

While our study offers insights on the capability of two pivotal aspects of engineering education to foster the same or similar professional skills, there are a number of limitations in this study which can and should be addressed in future work. This study was performed at a single Midwest university in the United States using one instance of a design course and entrepreneurship course to draw conclusions. The uniqueness of both the design and entrepreneurship courses also limited our ability to draw broad conclusions about design and entrepreneurship more generally. Additionally, this study was limited in the types of statistical analyses it could perform due to the sample size and the differing demographics of the two course populations. Due to demographic differences in our two sample populations, we avoided making statistical claims about direct comparisons between the courses. Future studies wishing to do this could duplicate the pre-post nature of the study, but work to use a larger sample size, include multiple universities from various backgrounds (i.e., R1 institutions, liberal arts colleges, historically black institutions, etc.), incorporate multiple instances of each course type, and better match the demographics of the two student populations of comparison. Accounting for these aspects of a study would allow researchers to ask more detailed questions about relationships not only with the course, but with other important factors such as student demographics and institutional characteristics. For example, researchers could explore how students' previous formal entrepreneurship coursework or informal experiences relate to the development of professional skills.

The purpose of our study was not to compare engineering entrepreneurship and design courses on their effectiveness, rather we focused on examining potential shared learning outcomes in the context of development of professional skills in engineering graduates. To better inform future efforts transforming teaching and learning in engineering fields, more research needs to be conducted in examining the development of professional skills in entrepreneurship and design courses across different engineering disciplines, institutional environments, and student populations. Future studies have the potential to identify best practices for developing professional skills for the two approaches (design and entrepreneurship), and provide evidence-driven implications for implementing such programs and more importantly integrating the two approaches in undergraduate engineering curriculum.

6. Conclusions

Existing literature offers strong advocacy for engineering entrepreneurship and design courses as a platform for developing 21st century skills in engineering undergraduates. While there exists overlap between the two approaches in terms of pedagogy and goals, potential overlapping professional skills have been minimally addressed in the engineering education literature. Our exploratory study examined the development of three potential professional skills (creative self-efficacy, risk-taking and entrepreneurial self-efficacy) in BME design and entrepreneurship courses. Our pre-post assessment results demonstrate that apart from searching, there was minimal overlap within perceived gains in professional skills between the two approaches. This indicates that the aspect of opportunity or problem identification is similarly addressed in the two approaches. However, the presence of differing impact on all other professional skills between the two approaches highlights that the integration of entrepreneurial training into existing design education courses will require more thoughtful course design to ensure that the curriculum and pedagogy are aligned to foster the development of all professional skills in addition to the ability to identify problems to solve.

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