Advances in Engineering Education

WINTER 2016

Faculty and Student Perceptions of the Content of Entrepreneurship Courses in Engineering Education

MARY BESTERFIELD-SACRE
University of Pittsburgh
Pittsburgh, PA

SARAH ZAPPE
The Pennsylvania State University
University Park, PA

ANGELA SHARTRAND
VentureWell
Amherst, MA

AND

KIRSTEN HOCHSTEDT
The Pennsylvania State University
University Park, PA

ABSTRACT

Entrepreneurship programs and courses in engineering education have steadily increased in the United States over the past two decades. However, the nature of these entrepreneurship courses and programs and the characteristics of the instructors who teach them are not yet well understood. The paper explores three research questions: 1) What content is typically included in engineering entrepreneurship courses and how is this content taught?; 2) What are instructors' beliefs about how entrepreneurship should be taught in the engineering context; and 3) How are instructors' beliefs actuated within a particular class related to students' self-reported perceptions of their entrepreneurial knowledge and abilities? The study shows that content associated with different course types, such as *Becoming an Entrepreneur*, *New Venture Development*, and *Product Ideation and Development*, often overlaps substantially, suggesting a lack of clarity in how these types of courses are defined. Second, instructors who teach entrepreneurship to engineering students believe that programs and courses should focus equally on both teaching skills and developing values and attitudes; and instructors feel confident in their ability to focus on both of these in their courses. Finally, at the end of the entrepreneurship course, students' perceptions of their own abilities were found to be similar to their instructors' intentions for the courses, particularly for students with less

entrepreneurial experience as measured by their coursework, involvement in entrepreneurship-related activities (e.g., clubs, competitions). As students' prior experience with entrepreneurship increased, they reported greater familiarity with concepts than expected given their instructors' intentions.

Key words: entrepreneurship, faculty perceptions, assessment, student perceptions

BACKGROUND AND STUDY OBJECTIVES

Research on entrepreneurship in the field of engineering education is in its early stages, despite the fact that entrepreneurship programs and courses in engineering education have steadily increased over the past two decades. While many examples of individual courses and programs of study have been published in the literature (e.g., Nichols & Armstrong, 2003), a comprehensive and systematic analysis of what, why, and how undergraduate engineers are taught entrepreneurship is lacking.

Research on Engineering Entrepreneurship Programs

Early work on this topic focused on documenting the process of course or program creation, describing content, pedagogy, implementation issues, and assessment plans (Wang & Kleppe, 2001; Carlson & Sullivan, 2000; Sullivan, Carlson & Carlson, 2001; Creed, Suuberg & Crawford, 2002). Exploratory and qualitative methods (Standish-Kuon & Rice, 2002) or quantitative studies with very small sample sizes were common. While these studies provided insight about student experiences in the particular context examined, they were limited in terms of generalizable knowledge (Bilén, Kisenwether, Rzasa & Wise, 2005). While Duval-Couetil, Reed-Rhoads, and Haghighi (2011) assessed learning among more than 500 engineering students, the sample was drawn from entrepreneurship programs at three institutions. These findings suggest the need to examine a larger set of institutions.

One reason for the dearth of comprehensive, systematic research in engineering entrepreneurship to date is the difficulty identifying cohesive programs of study. Previous research on ASEE member schools found that a small proportion - about 12% - offered a minor, certificate or major in entrepreneurship (or similar program naming) (Besterfield-Sacre, Ozaltin, Shuman, Shartrand & Weilerstein, 2011). While this does not capture all entrepreneurship education opportunities that are being offered to engineers, other studies indicate that entrepreneurship is not widely offered in the context of engineering education. Several recent surveys of engineering faculty and administrators' attitudes shed some light on why this may be.

The *Innovation with Impact (IWI)* report (ASEE, 2012) included findings from a survey of 110 engineering departments from 72 colleges and concluded that "newer" learning environments,

such as those incorporating entrepreneurship, are generally not valued by engineering faculty (ASEE, 2012). At the undergraduate level, 52% of departments, consisting of faculty committees, responded that entrepreneurship was not important to an engineering curriculum. At the graduate level, this percentage was even higher. Likewise, a subsequent survey of 144 engineering faculty and administrators from 90 institutions conducted on behalf of the NSF-Funded Epicenter at Stanford (Peterfreund, 2013) indicated that entrepreneurship is not widely practiced. Specifically, very few respondents said that their institutions included entrepreneurship and innovation as part of the core curriculum. In contrast with the *IWI* survey, however, these respondents (who primarily were at ASEE member institutions) expressed overwhelming interest in increasing elective courses and extra-curricular activities and believed that entrepreneurship *should* be included in the core curriculum of engineering.

Though not yet widely practiced or consistently valued, Smith, Sheppard, Johnson and Johnson (2005) note that educational experiences such as entrepreneurship and service learning have been shown to increase diversity and retention in engineering. While the statistics indicate that many engineering faculty are lukewarm to incorporating entrepreneurship in their curriculum, other evidence indicates that some faculty are supportive of the idea and see the potential value of teaching entrepreneurship in undergraduate engineering. *Therefore, the purpose of this study was to examine instructional practices, faculty beliefs, and student outcomes related entrepreneurship in engineering with a larger group of programs that are actively engaged in offering these experiences to students.*

Faculty Beliefs: Influences on Content, Curriculum Design, and Pedagogy

Given the mixed findings on faculty attitudes about entrepreneurship cited above, it is important to understand how faculty beliefs influence entrepreneurship education content, curricular design and pedagogy. The question of whether faculty think entrepreneurship is teachable has been examined in depth by Henry, Hill, and Leitch (2005a; 2005b) who acknowledge that most faculty would likely believe that entrepreneurship could be taught, given the number of institutions offering courses in the area. Zappe, Hochstedt, Kisenwether and Shartrand (2013) examined engineering entrepreneurship instructors' perceptions of whether entrepreneurship is "teachable" to test this assumption. Indeed, in their sample of 37 instructors, most believed that the necessary skills and attributes needed to be an entrepreneur could be learned. Again, this is not surprising given that these instructors were teaching courses in entrepreneurship. That being said, instructors were likely to acknowledge that certain attributes of entrepreneurs, such as passion, vision, and drive, were more difficult to develop than skills related to problem solving, acting on opportunities, and business. One limitation of the study is that the sample was restricted to instructors at only three large, research-focused institutions. Several more comprehensive analyses of general entrepreneurship

education in business and management departments have been conducted (Vesper & Gartner, 1997; Solomon, Duffy & Tarabishy, 2002; Bennett, 2006). This study will examine perceptions relating to the innateness of entrepreneurship skills with a broader sample of engineering entrepreneurship instructors from a variety of institutions.

Faculty beliefs also inform curricular design in entrepreneurship education. Okudan and Rzasa (2004)'s review of the literature identified four key areas that informed curricular design: a) "affective socialization," such as values and attitudes associated with entrepreneurship; b) making decisions with "insufficient information" or risk taking; c) a "learning style" that addresses active experimentation; and d) "adoption of entrepreneurial behavior[s]" such as independent action, competitive aggressiveness, proactiveness, and innovativeness (Lumpkin & Dess, 1996).

In terms of instructional approaches, although some prior research suggests that a dominant instructional technique is not evident (Michael, 2007), prior work suggests that frequently used instructional practices include experiential learning, offering students opportunities to practice entrepreneurial skills, and providing mentorship (Zappe et al., 2013). The range of instructional techniques cited in the literature to teach entrepreneurship to engineers includes problem-based learning (Warren, Kisenwether & Hanke, 2006), project-based learning (Okudan & Rzasa, 2006), case studies (Weaver & Rayess, 2008), and product development (Birmingham, Allison & Dupree, 2007).

Student Outcomes of Entrepreneurship Education

Improving student outcomes are the central purpose of entrepreneurship education in engineering. Prior research suggests that entrepreneurship programs can enhance engineering students' educational outcomes, student satisfaction, and longer-term professional careers. Ohland, Frillman, Zhang, Brawner and Miller (2004) looked at the impact of entrepreneurship education on engineering students' GPAs and retention rates and found that entrepreneurship education had a positive impact. Other studies have been examined student satisfaction with the course and self-perceived growth in particular areas such as creativity, leadership, and teamwork (Dabbagh & Menascé, 2006; Okudan & Rzasa, 2006; Bilén et al., 2005; Ragusa, 2011). Charney and Libecapp (2003) evaluated the Berger Program in Entrepreneurship at the University of Arizona, examining the long-term impact on graduates relative to three areas: starting new ventures, self-employment, and earnings. A matched comparison with non-entrepreneurship business graduates showed positive effects of the program on these same areas.

Though the above studies are informative, faculty need better tools to assess what entrepreneurial knowledge and skills students are acquiring in courses and programs so they can improve teaching and optimize program development. Duval-Couetil et al. (2011) reviewed the assessment literature in

entrepreneurship education and found that three main areas of work: 1) course level evaluations that measured student reactions; 2) instruments designed to measure entrepreneurship-related activities; and 3) program-level evaluations that are designed address broader entrepreneurship program related outcomes. Pittaway, Hannon, Gibb, and Thompson (2009) offer a framework for the various entrepreneurial competencies that can be used in classifying types of assessment; and many new instruments are being created for this purpose in engineering to include the many outcome related rubrics developed by the KEEN group (www.keennetwork.org), self-efficacy of entrepreneurship (Lucas and Cooper, 2009), as well as student attitudes (Shinnar & Pruett, 2009). For the most part, many of these assessments focus on shorter-term impacts on students' entrepreneurial skills and knowledge (Falkang & Alberti, 2001). This research is no exception; however, we attempt to pair students' self-perception with instructors' intention.

Research Questions

The following research questions are explored in this paper:

1. What content areas are typically included in engineering entrepreneurship courses (particularly those focusing on venture creation and product development) and how is this content taught?
2. What are instructors' beliefs about how entrepreneurship should be taught in the engineering context? Is there an overarching relationship between instructors' beliefs about entrepreneurship and the content that is taught?
3. Is there a relationship between instructors' beliefs actuated within a particular class and students' self-reported perceptions of their entrepreneurial knowledge and abilities?

In settings where engineering-based entrepreneurship coursework is offered, we sought to better understand what, how, and why faculty teach this content to engineers. In particular, what instructional techniques are used to teach entrepreneurship? Why do instructors teach entrepreneurship in the manner they do?

The second research question concerns whether or not instructors believe that programs and courses should focus on skill development rather than instillation of attitudes and values necessary for successful entrepreneurs. More specifically, what experiences do instructors draw on when determining the content to emphasize in their courses? Many instructors of entrepreneurship, though engineers, have strong entrepreneurial and business backgrounds.

This work is important in understanding what entrepreneurship concepts that are being taught in the United States (i.e., the content), the beliefs among those who are teaching these concepts, and the pedagogical approaches being used (i.e., the pedagogy). To date, little information is known about what constitutes the body of knowledge of entrepreneurship in engineering education or how this body of knowledge and skills is best taught to engineering students.

METHODS

To examine the three research questions, instructors and students each completed an online survey. A total of 25 instructors (16 instructors from spring 2012 and 9 instructors from summer 2012) who taught entrepreneurship within the engineering context completed the Entrepreneurship Faculty Beliefs Survey and Faculty Entrepreneurship Knowledge Inventory (EKI). A total of 325 students, enrolled in the spring 2012 courses taught by instructor participants fully completed the Student Entrepreneurship Knowledge Inventory (EKI). This consisted of 13 of the 16 faculty since not all instructors were teaching their particular course during the spring term. Human subjects consent for both aspects of this study (instructor and student) was obtained by both the University of Pittsburgh and the Pennsylvania State University. Information on recruitment of participants and description of the instruments follows.

Recruitment of Instructor Participants and Their Students

In the spring of 2011, a review of course catalogs at 345 ASEE schools in the U.S. was conducted to identify entrepreneurship programs of study that were accessible to undergraduate engineering majors. Based on a cluster analysis (Besterfield-Sacre et al., 2011), we identified engineering programs that focused their entrepreneurship programs around certain course attributes. The project team identified more than 100 entrepreneurship programs that served undergraduate engineering students, 40 of which were administered solely or jointly by schools and colleges of engineering. Program directors at the 40 institutions were contacted and were asked to identify at least one instructor who was teaching a product development or venture development in their entrepreneurship program. Referrals from program directors resulted in 16 instructors who agreed to participate for a nominal honorarium.

These instructor participants were asked to complete the Faculty Beliefs Survey and Faculty EKI. They were also asked to administer the student version of the EKI to their students in the product development or venture development course they were teaching in spring 2012. The instructors were provided with an anonymous link to the online student survey, which they were asked to distribute to students enrolled in their course. Some of the instructors provided an incentive (i.e., extra credit points) to students who completed the survey. Through this recruitment method, we received 16 responses on the faculty survey; and of those faculty, 13 implemented the EKI in their spring course resulting in 325 valid responses.

While the sample size for students was fairly large, the number of participating instructors was relatively small. To increase the number of respondents, an additional recruitment strategy was used. An announcement publicizing the study was sent to the ASEE Entrepreneurship Division listserv and was posted in two monthly E-bulletins of the National Collegiate Inventors and Innovators

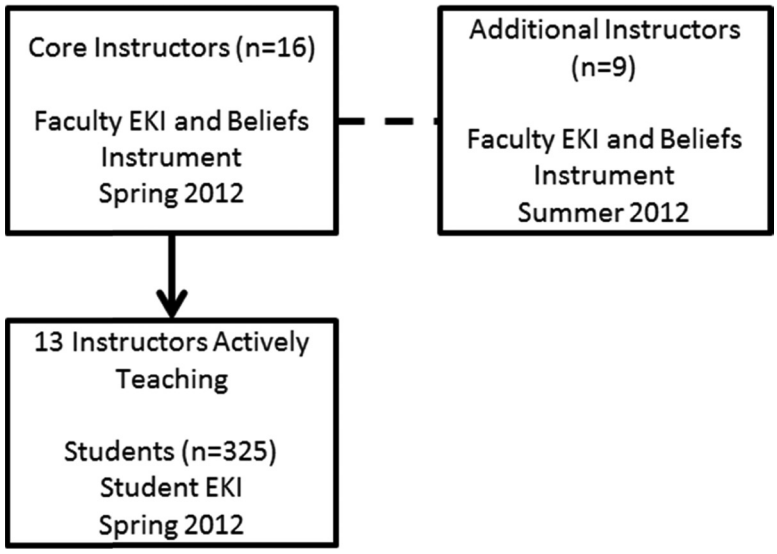

Figure 1. Data collection strategies used in the study.

Alliance (formerly NCIIA, now VentureWell). The announcement described the study and requested participation from faculty and instructors who teach entrepreneurship to engineering students. These instructors were asked to complete the faculty instruments, but were not asked to have their students complete the student survey. An additional nine participants were identified in this manner for a total of 25 instructor participants. Figure 1 provides a graphical description of the data collection strategies used in this study.

All faculty respondents were used in addressing the first two research questions. The third research question utilized data only from the 13 instructors who administered the questionnaire to their students during the term they were teaching the course. For this analysis we pooled the 13 instructors to have a sample size substantially large enough to compare their responses to that of the students. It is recognized that some differences may exist between faculty intentions for their courses, which research question one addresses.

Instruments

Two primary instruments that were used in carrying out this research are described below.

Student Entrepreneurship Knowledge Inventory (EKI)

The student-version of the EKI, developed and tested in 2007, is an inventory consisting of 105 items intended to measure students' familiarity with entrepreneurial terms in five areas: 1) Becoming

Subject Areas	Identified Factors
Becoming an Entrepreneur	1. Strategic Thinking & Presentation
	2. Process & Context
	3. Structure & Approach
	4. Entrepreneurship
Financing & Accounting	5. Core finance
	6. Venture Launch/ Funding
	7. Reporting
People & Human Resources	8. People and Human Resources
Sales & Marketing	9. Sales and Marketing
Product Ideation & Development	10. Intellectual Property
	11. Meeting a need
	12. Protecting an Idea

Table 1. Subject area identified factors.

an Entrepreneur, 2) Finance and Accounting, 3) People and Human Resources, 4) Sales and Marketing, and 5) Product Ideation and Development. The various items were clustered into 12 factors listed in Table 1.

Further, in each category, students were asked to rate their familiarity with a set of terms using a 5-point rating scale. The anchors on the scale are:

- None (Never Heard of it)
- Low (Heard of it but not sure what it means)
- Moderate (Can explain it partially)
- High (Can explain in depth but not sure how to apply it
- Very High (Can explain in depth and can apply it)

The student survey was conducted using Qualtrics™, an online commercial survey package (Qualtrics Labs Inc., Provo, UT). The students responded to the inventory items with respect to the course they were taking. In addition, students remarked on the number of entrepreneurship courses they previously had taken, as well as other entrepreneurial experiences (e.g., clubs, mentorships, business competitions). A large-scale study of ten engineering schools that implemented the Student EKI is described in Besterfield-Sacre, Robinson, Ozaltin, Shuman, Shartrand and Weilerstein (2012). As part of this study, significant differences in scores have been found between freshmen and senior engineering students. Further, as part of its initial development, the instrument was used in a pre-post manner across eight schools as part of a prior VentureWell project to develop and pilot tools to measure entrepreneurship education outcomes. These studies provide growing validity evidence for the instrument in terms of the relationships with other variables, including group membership (freshmen vs. senior), time of administration (pre/post),

and school type. The reliability of the instrument, as measured by Cronbach's α, is greater than or equal to 0.90 for all five factors. The validity of the instrument has been measured through both expert review as well as group comparisons (Shartrand, Weilerstein, Besterfield-Sacre & Olds, 2008). Further, the instrument was built using an established taxonomy of entrepreneurship (Kussmaul, Howe, Arion, Farris, Goodrich, Lane, Lehman, Levenburg, Kundrat, Secor, Twitchell, Way, & Weissbach, 2006).

Entrepreneurship Faculty Beliefs Survey and Faculty EKI

The second instrument used in the study was intended to gather information from faculty and instructors who teach entrepreneurship to engineering students. The faculty survey consisted of two parts. First, instructors were asked to complete a revised version of the Entrepreneurship Faculty Beliefs Survey, which was initially constructed in 2009. The purpose of this instrument is to gather information on four primary questions:

- How do instructors define entrepreneurial mindset, or the characteristics necessary to be an entrepreneur?
- Do instructors feel the mindset is innate? Or do they feel it can be developed with training?
- What teaching methods do instructors use to teach entrepreneurship to engineers?
- Is there a relationship between instructor beliefs and the teaching methods they employ?

More information on the construction of the survey and initial results are available (Hochstedt, Zappe, & Kisenwether, 2010; Zappe, Hochstedt, & Kisenwether, 2012; Zappe et al., 2013). For this paper, the instrument was revised to reduce its length by removing items that were less central to this study. In addition, instructors were asked to choose a category that fit best with the entrepreneurship course they taught. The options were: 1) *Venture Development*, 2) *Product Ideation and Development*, or 3) *Becoming an Entrepreneur*.

The second part of the online instrument consisted of a faculty version of the EKI. The faculty survey included the same items as the student version of the EKI, but instead of rating their familiarity with terms, instructors were asked to indicate the degree to which the terms were emphasized in their course. The anchors on the scale are the following.

- None (Term is not used in the course)
- Low (Term is used in the course, but the students are not expected to understand it)
- Moderate (Term is used in the course and the students are expected to understand it partially)
- High (Term is used in the course and the students are expected to understand it in-depth)
- Very High (Term is used in the course and the students are expected to understand it in-depth and apply it)

This study represents the first administration of the faculty EKI; as such validity of the instrument and its scale has not been determined. Note, that although the terms are the same across the student EKI and the faculty EKI, the scale is specifically designed to capture what instructors believe they emphasize in their course, whereas the student EKI is designed to measure students' degree of familiarity with using and applying the particular terms and skills. It is the comparison between these two scales that is the focus of the third research question. As a result, in comparing students' perspectives to those of the instructors, we utilized the same factor structure. Unlike the student version of the EKI, no reliability or validity information is provided for the faculty version of the EKI as this study is the first time using the instrument; however, both instruments are in essence the same.

Data analysis

To answer research question 1, which asks about the typical content areas and instructional techniques used to teach engineering entrepreneurship, instructor responses on the Faculty EKI were examined. As mentioned previously, instructors self-selected which type of entrepreneurship course they were teaching: (1) *Venture Development*, (2) *Product Ideation and Development*, or (3) *Becoming an Entrepreneur*. In the actual survey, the participants were asked to indicate the degree to which terms were emphasized in their course on the mentioned scale. This translated to a numerical scale from one to five. These values were then collapsed into the corresponding weighted factor value for each of the items, resulting in 12 distinct topic areas, so the faculty factor ratings shown in the graphs are not whole numbers.

Between the two samples, sufficient instructor samples for each category were obtained to conduct a one-way analysis of variance (ANOVA) on the 12 factors to determine if differences existed among the three types of entrepreneurship courses. Items were tested with a type I error of 0.05. For those factors in which differences existed, a post hoc Tukey's analysis was further conducted to determine specific differences. For those particular differences, an item-by-item analysis was then conducted to determine particular knowledge and skills that differ among the three types of courses.

To answer research question 2, which concerns why instructors teach in the manner that they do, the responses from the Faculty Beliefs Survey were examined. Certain questions were specifically targeted to examine the following sub-questions: Do entrepreneurship instructors feel that the skills necessary to be an entrepreneur are innate or developed? Which skills do they believe are more easily taught and which do they believe are more innate? Do entrepreneurship instructors have teaching goals that are more focused on skills rather than instilling attitudes and values necessary to be an entrepreneur? What characteristics do they feel they can most influence in their students? Analysis for research question 2 is primarily descriptive in nature.

Finally, as with research question 1, a similar approach was taken for research question 3. T-tests were initially performed to determine if differences existed between an instructor's beliefs in what was taught and their students' self-reported perceptions of entrepreneurial knowledge and abilities. Then, one-way ANOVAs were conducted on subgroups of gender, major, and experience to determine if differences existed in students' background and the instructors' course intentions.

Participants

Twenty-five instructors participated in the study; representing 23 unique institutions (two institutions had two instructors each complete the instrument). Of these, 23 were male and two were female. They were employed by a variety of institutions across the United States. Institutions ranged in size from small design-focused schools to large research institutions. One individual left a substantial number of questions blank on the EKI and as a result was removed from analysis of research question 1. Table 2 displays participants' positions in their institutions. Of the 24 individuals who responded to the question, 15 held non-tenure track positions, eight were tenured, and one was in a tenure-track position. Participants in the "other" category reported being a department head, emeritus faculty, or a director of an entrepreneurship program. Participants were affiliated with various departments, including business/management (N=3), engineering disciplines such as mechanical, industrial, chemical, and biomedical engineering (N=13), and entrepreneurship or innovation programs (N=7). In addition, one respondent was from the School of Information and one respondent left this blank.

Some instructors had entrepreneurship-related experience. Nine (36%) held patents, 21 (84%) had worked in a small start-up company, and 15 (60%) had worked in an "innovation" segment of a large company.

Of the instructors surveyed, 13 were actively teaching the spring 2012 term and administered the student EKI to their students for the particular course in which they themselves answered on the faculty EKI. Table 3 provides an overview of the student demographics across these 13 courses. The

Position	Percentage	Number
Full Professor	32	8
Associate Professor	12	3
Assistant Professor	8	2
Instructor or adjunct	36	9
Other	12	3

Table 2. Positions held by respondents.

Demographic	Percentage	Range
Ethnicity		
White	60.3%	36%–100%
Black or African American	6.5%	0%–11%
Hispanic or Latino	3.4%	0%–17%
American Indian and Alaska Native	0.3%	0%–2%
Asian	24.6%	0%–51%
Native Hawaiian/Pacific Islander	0.0%	N/A
Some other race	1.5%	0%–5%
Prefer not to answer	3.4%	0%–11%
Gender		
Male	72.1%	0%–89%
Female	27.0%	11%–100%
Prefer not to answer	0.9%	0%–25%
Experience		
Low	59.0%	0%–100%
Moderate	26.0%	0%–70%
High	15.0%	0%–48%
Level in School		
Freshman	0.8%	0%–5%
Sophomore	4.1%	0%–16%
Junior	34.2%	0%–75%
Senior	54.5%	19%–100%
Graduate Student	6.5%	0%–17%
Major		
Engineering student	71.1%	0%–100%
Not an engineering student	22.2%	0–68%
Other and Unclassified/Undeclared	6.8%	0–100%

Table 3. Student demographics.

demographics are self-explanatory with the exception of experience. We defined students' degree of entrepreneurship experience based on the number of courses they had taken previously as well as the degree of involvement they had in entrepreneurial activities. Further, because some demographic groups were not represented across several of the 13 schools group comparisons were not conducted on these variables. For example, several courses had only White respondents, so it was not possible to do group comparisons for *ethnicity*. Similarly, group comparisons were not conducted on *level in*

school, since technical electives in engineering are typically taken by upper class students only. Group comparisons were conducted on gender, experience, and major. A notable exception is a course that had survey responses from only female students with little to no experience. Results of the various analyses are explained in section 3.

RESULTS BY RESEARCH QUESTION

The following sections provide an overview of the results by each research question.

What content areas are typically taught in engineering entrepreneurship courses?

Three types of courses were examined (i.e., *Becoming an Entrepreneur, Venture Development*, and *Product Ideation and Development*). Content was measured by the degree to which each factor was taught. Nine instructors categorized their course as focused on *New Venture Development* (NVD); eight categorized their course as focused on *Product Ideation and Development* (PID); and seven categorized their course as focused on *Becoming an Entrepreneur* (BE). Table 4 provides an overview of the descriptive statistics for each course type and each factor.

Results indicate that regardless of course type, instructors emphasize similar topics, with the exception of three particular factors: Venture Launch/Funding, Reporting, and Meeting a Need. For each of

Factor	New Venture Development N=9	Product Ideation & Development N=8	Becoming an Entrepreneur N=7	P value
1. Strategic thinking and presentation	3.60 (*0.39*)	3.76 (*0.35*)	3.74 (*0.77*)	0.800
2. Process and context	2.85 (*0.49*)	3.17 (*0.67*)	3.00 (*0.78*)	0.580
3. Structure and approach	3.65 (*0.41*)	3.03 (*0.45*)	3.37 (*0.82*)	0.105
4. Entrepreneurship	3.42 (*0.42*)	3.51 (*0.60*)	3.68 (*0.59*)	0.660
5. Core Finance	2.87 (*0.69*)	2.09 (*0.76*)	2.79 (*0.91*)	0.095
6. Venture Launch/Funding	3.16 (0.58*)*	1.92 (*0.37*)	3.16 (*1.14*)	**0.003**
7. Reporting	3.13 (*0.66*)	1.84 (*0.58*)	3.17 (*1.43*)	**0.014**
8. People & Human Resources	3.85 (*0.60*)	3.29 (*0.87*)	4.29 (*0.64*)	0.052
9. Sales and Marketing	3.54 (*0.47*)	3.71 (*0.63*)	3.21 (*1.26*)	0.515
10. Intellectual Property	3.38 (*0.60*)	3.15 (*0.57*)	3.08 (*1.08*)	0.706
11. Meeting a Need	3.53 (*0.49*)	4.36 (*0.45*)	3.44 (*1.23*)	**0.037**
12. Protecting an Idea	3.34 (*0.89*)	2.44 (*0.88*)	3.49 (*1.30*)	0.093

Table 4. Mean differences between the three types of entrepreneurship courses (standard deviation).

these factors, the Tukey's post hoc analysis yielded that PID was significantly different than the other two course types. Specifically, instructors who teach PID courses said they placed significantly less emphasis on Venture Launch/Funding and Reporting aspects than instructors who teach NVD and BE courses. While the terms associated with these two factors may be used in the course, students are not expected to understand them. Thus in PID courses, terms such as venture capital, due diligence, equity, cash flow statements, payable/receivables, etc., may be mentioned to students, but students are not required to have a firm understanding of these areas. Conversely, instructors who teach PID courses said that they placed significantly more emphasis on Meeting a Need than instructors who teach NVD and BE courses. Here, instructors who teach PID courses expect their students to not only understand Meeting a Need in-depth, but also expect students to apply their knowledge and skills in this area. This is to be expected as Meeting a Need lies at the heart of Product Ideation and Development. Interestingly, no differences were found for two other factors that would be expected to have a strong emphasis in PID courses, Intellectual Property and Protecting an Idea. Interestingly, Protecting an Idea was rated somewhat lower (though not significantly) by instructors teaching PID courses compared to instructors teaching NVD and BE courses. It should be noted that this analysis is the result of 24 instructors from 23 unique institutions reporting on the particular entrepreneurship course offered to engineering students in a particular term. Prior research indicates that there are approximately 100 entrepreneurship programs across the U.S. that served undergraduate engineering students; and of these, 40 programs are housed directly within an engineering school (Shartrand, Weilerstein, Besterfield-Sacre & Golding, 2010). Though it is not possible to estimate the total number of faculty who teach entrepreneurship to engineers, this sample does appear to be representative of the types of entrepreneurship courses typically taught in engineering schools.

Two additional areas regarding the faculty EKI warrant consideration. First, from Table 4, it is shown that instructors teaching all types of entrepreneurship courses place a low to moderate emphasis on Core Finance (i.e., students not expected to understand it or only partially). Core Finance items included projections and forecasts, risk analysis, fixed costs versus variable costs. Second, given our type I error of 0.05, People and Human Resources was not found to be significantly different among course types (*P*value=0.052); however, examination of the means (and standard deviations) indicates that instructors teaching BE courses say that they place a high emphasis on People and Human Resources. In other words, instructors expect their students to have a deep understanding of the items associated with this factor.

Instructors' beliefs about how entrepreneurship should be taught in engineering

Participants were asked to use a sliding scale to indicate where between mostly innate (0) or mostly developed or learned (100) the necessary characteristics to be an entrepreneur lie. Not

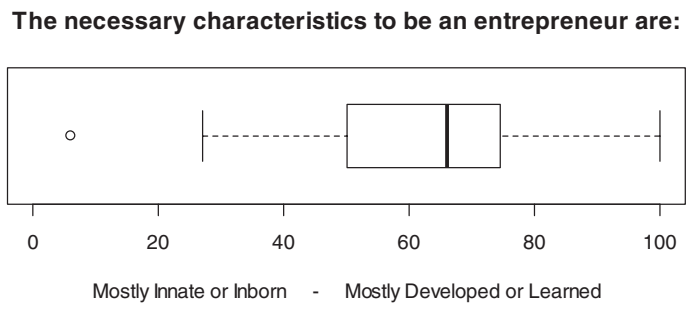

Figure 2. Boxplot of instructors' perceptions on whether necessary characteristics to be an entrepreneur are innate or developed.

surprisingly, most respondents indicated that the skills necessary to be an entrepreneur are mostly developed or learned. Figure 2 displays a boxplot describing the distribution of responses. The average score on this item was a 63.71 (s=20.7). Given that the midpoint of 50 indicates a perception that the characteristics are equally innate and developed, the average score of 63.71 indicates a tendency for participants to believe that these skills can be mostly developed or learned. However, the spread of the data is fairly large, indicating that some respondents were also likely to view the characteristics as either mostly innate or equally learned and innate. One individual, whose response could be considered an outlier, felt strongly that the necessary characteristics were mostly innate. The results are fairly similar to those found by Zappe et al. (2013). In that sample of entrepreneurship instructors at three large research institutions, most respondents felt that necessary characteristics to be an entrepreneur could be learned.

Respondents were presented with a list of entrepreneurship attributes and skills and were asked to select those that were more easily developed or learned, on one hand, and those that were more innate or inherent to personality on the other. Figure 3 displays the percentage of respondents who selected each characteristic. Instructors selected technical skills, business skills, problem solving, and communication items as the attributes that were most easily developed or learned. Instructors selected curiosity, drive, passion, being outgoing, and ambiguity tolerance as the attributes that were more innate or inherent to personality. The sample was more evenly divided concerning attributes such as ability to act on opportunities, failure acceptance, interpersonal skills, ability to adapt, risk taking and vision.

Participants were also asked a series of questions regarding whether or not entrepreneurship instruction should focus on skill development versus instilling attitudes and values (See Figure 4). While the mean response to this item was very close to the middle, at 47.36 (s = 23.64), the range is 84, which is very large (minimum=13; maximum=97). Eight individuals scored this with a "50"

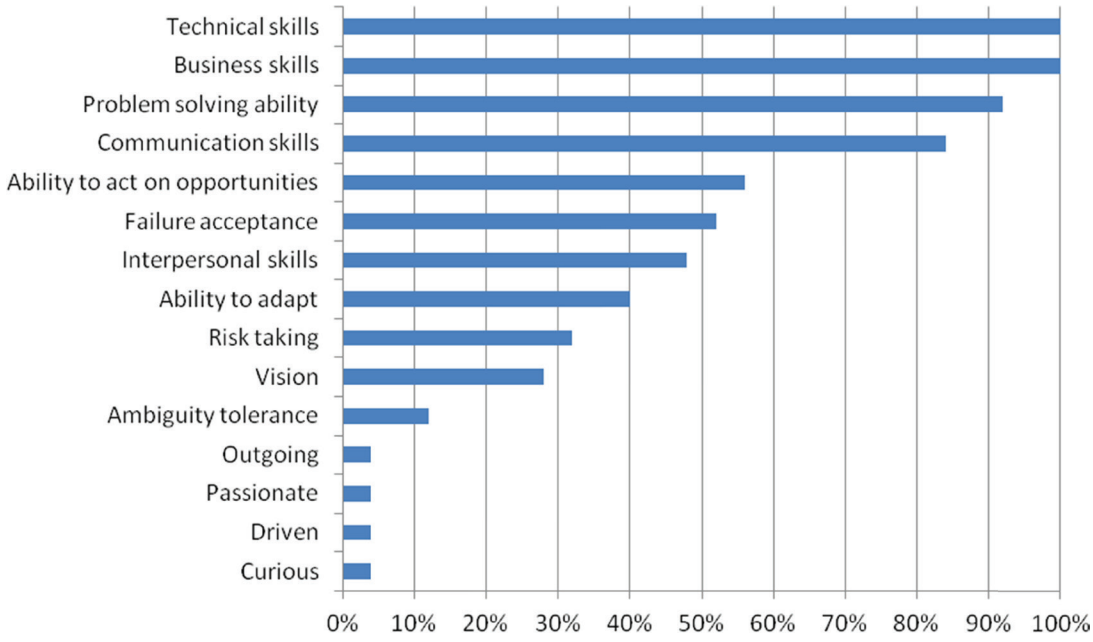

Figure 3. Percentage of respondents who identify each characteristics as more easily learned.

meaning that they believe programs should focus equally on skills and instilling attitudes. The other respondents disagreed on the focus of these programs. Three individuals responded strongly that programs should focus on instilling attitudes and values. However, the majority of respondents either felt there should be equal emphasis on instilling attitudes and teaching skills or that programs should focus on developing skills.

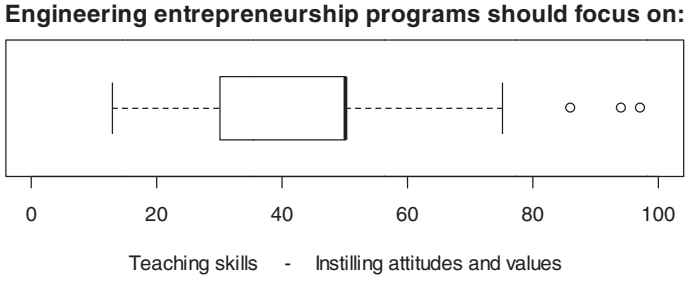

Figure 4. Boxplot of instructors' perceptions on whether programs should focus on teaching skills versus instilling attitudes and values.

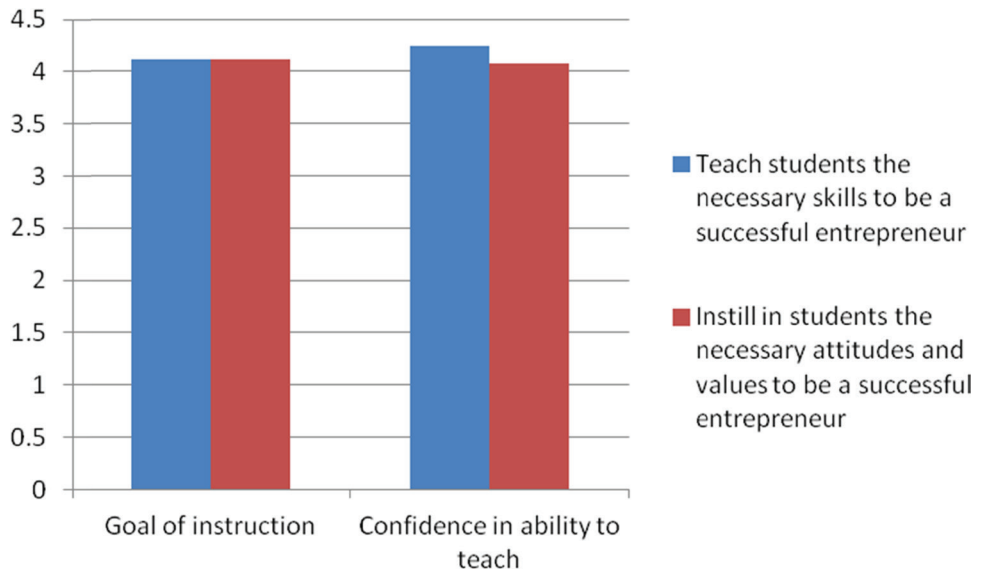

Figure 5. Participants' goals of instruction and confidence in ability to teach.

Participants rated statements about their instructional goals and their confidence in teaching students either skills or attitudes and values necessary to be an entrepreneur. Figure 5 displays a column chart comparing responses regarding instructional goals and confidence for teaching either skills or attitudes. The average item scores for the goals of instruction for skills and attitudes/values were identical, resulting in a nonsignificant result (t=0.000, df=24, Pvalue=1.000). Participants' ratings of their confidence for teaching skills and attitudes were not significantly different (t=0.66, df=24, Pvalue=0.516). This suggests that instructors have dual goals in their courses of teaching skills and instilling attitudes and values necessary to be a successful entrepreneur. Additionally, their ratings suggest that they are confident that both can be done in their courses.

Participants also indicated characteristics they felt they could influence in their courses, shown in Figure 6. Instructors' felt they could impact students' self-efficacy (i.e., students' beliefs in their ability to be successful). They also gave high ratings to the following items: acting on opportunities, adapting to new situations, resourcefulness, learning from failure, and tolerating ambiguity. They gave lower ratings to characteristics that they felt were more innate to their students, such as passion, drive, and being outgoing.

Finally, participants indicated the degree to which certain experiences influenced the content covered in their entrepreneurship courses (see Figure 7). They rated their own career, personal, and entrepreneurial experiences highest. Their colleagues' teaching style and their personality had less impact on the content that they chose to focus on in their courses.

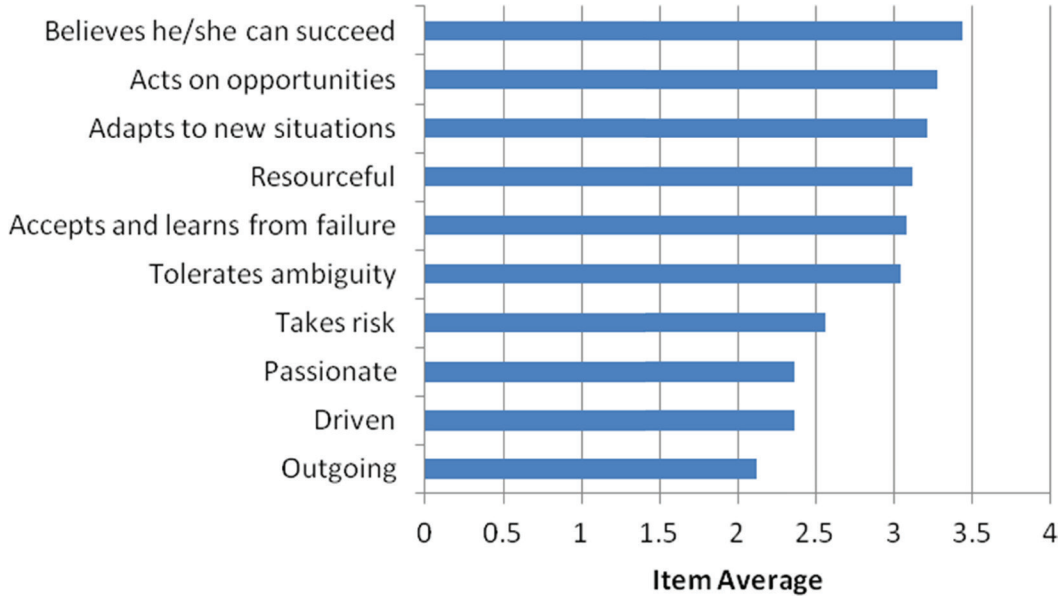

Figure 6. Participants' ratings regarding student traits they feel they can most likely influence.

The relationship between instructors' beliefs and students' perceptions

T-tests were performed to determine if differences existed between an instructor's beliefs in what was taught and their students' perceptions on what they believed they learned after taking the particular course. Because there are 12 factors, a Bonferroni adjustment for multiple comparisons was applied to the original Type I error, $\alpha = 0.05$. Therefore, the adjusted Type I error becomes $\alpha_{adj} = 0.004$ (0.05/12 factors). As Table 5 indicates, five of the 12 factors were found to have significant differences between instructor and students; and in all five cases, students rated their self-perceived familiarity higher than the instructors' indicated degree of course emphasis. This "overconfidence" is not surprising, as students may naively feel confident in their new knowledge. Interestingly, the five significant factors (Strategic Thinking & Presentation; Process and Context; Core Finance; Venture Launch/Funding and Reporting) were factors that instructors, on average, intended to use in the course, but not necessarily have students understand and apply (i.e., the factor averages were less than three).

To determine if the above results were a function of naïve overconfidence or a result of potentially another underlying factor, additional comparisons were made for student gender, major, and degree of experience. To test differences between male students, female students and instructors, a one-way ANOVA was conducted followed by, where appropriate, a Tukey's post hoc analysis to determine where specific differences existed. The same analysis was conducted on major (where the factors

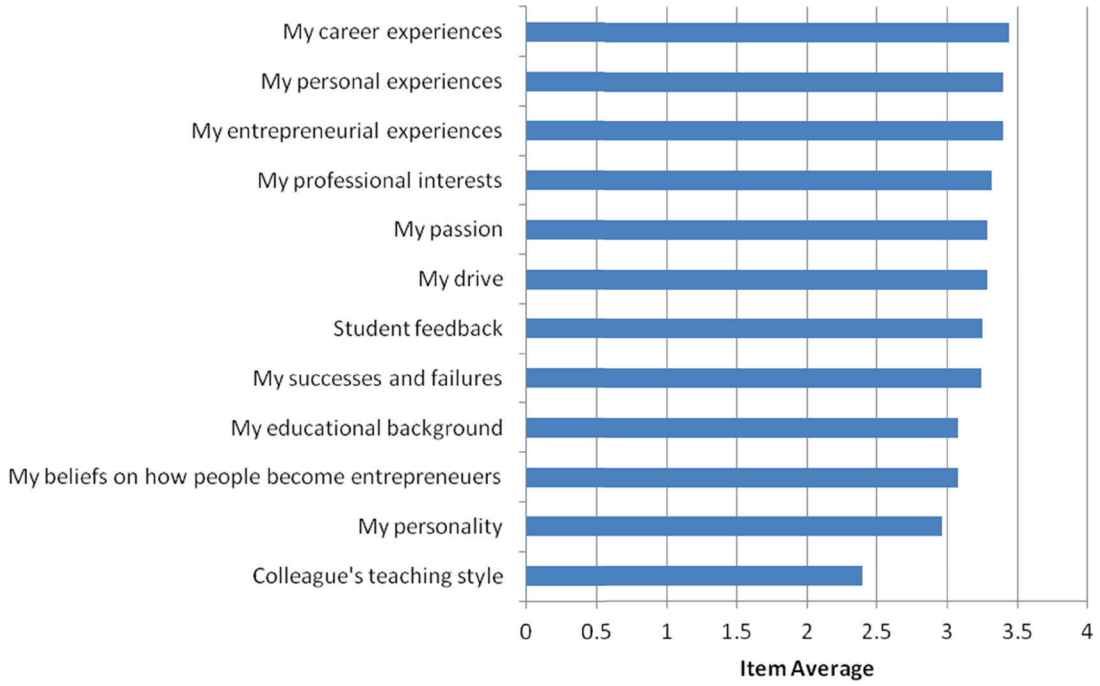

Figure 7. Items that instructors use to impact their classroom.

levels were engineering or non-engineering) and experience. There were no differences between the means of the students that majored in engineering and those that did not. Similarly, there were no significant differences between male and female students. Differences were found between students and instructors with respect to the five factors highlighted in the Table 5.

A portion of the EKI asked about the students' degree of experience, as shown in Figure 8. From the responses, students were divided into three levels of experience to determine the strength of their prior entrepreneurship experience (i.e., low experience, moderate experience, and high experience). A one-way ANOVA was conducted on the four levels (i.e., three levels of students and one level for instructor), with Tukey's post hoc analysis for those factors that proved significant. Students with low experience – i.e., had never taken an entrepreneurship course beyond the particular class in which the EKI was given - had perceptions that were similar to the instructors' intentions for the course, while students who had taken multiple courses in entrepreneurship and had exercised their entrepreneurship skills outside the classroom were significantly more familiar and comfortable relative to the various factors. As an example, the instructors' average rating of Core Finance was 2.41, while students with high experience rated this factor 4.48.

Factor	Student N=325	Instructors N=13	Pvalue
1. Strategic Thinking & Presentation	4.29 (0.62)	3.63 (0.52)	**0.000**
2. Process & Context	3.79 (0.74)	2.73 (0.67)	**0.000**
3. Structure & Approach	3.82 (0.68)	3.20 (0.74)	0.007
4. Entrepreneurship	3.72 (0.76)	3.45 (0.55)	0.086
5. Core Finance	4.12 (0.74)	2.41 (1.03)	**0.000**
6. Venture Launch/ Funding	3.92 (0.83)	2.81 (1.06)	**0.001**
7. Reporting	3.82 (0.88)	2.60 (1.19)	**0.001**
8. People and Human Resources	4.13 (0.74)	3.80 (0.76)	0.163
9. Sales and Marketing	4.10 (0.75)	3.62 (0.93	0.061
10. Intellectual Property	3.82 (0.82)	3.11 (0.72)	0.007
11. Meeting a Need	4.14 (0.72)	3.71 (0.93)	0.091
12. Protecting an Idea	4.12 (0.86)	3.17 (1.15)	0.009

Table 5. Mean differences between the students and instructors (standard deviation).

Interestingly, proportionally more non-engineering majors had high experience compared to engineering majors, as Table 6 indicates (χ^2=18.695, df=2, *P*value=0.000). Students majoring in engineering tended to have low experience in entrepreneurship (64%).

DISCUSSION

This research provides several empirical observations regarding the nature of how instructors teach entrepreneurship in engineering programs. First, although some differences do exist among course types, the content within the various courses appears to be less differentiated than it should be. Second, instructors who teach entrepreneurship do possess certain attitudes towards the nature

Experience	Non-Engineering	Engineering
High	26	23
Moderate	26	58
Low	42	150

Table 6. Number of Students by Major and Level of Experience.

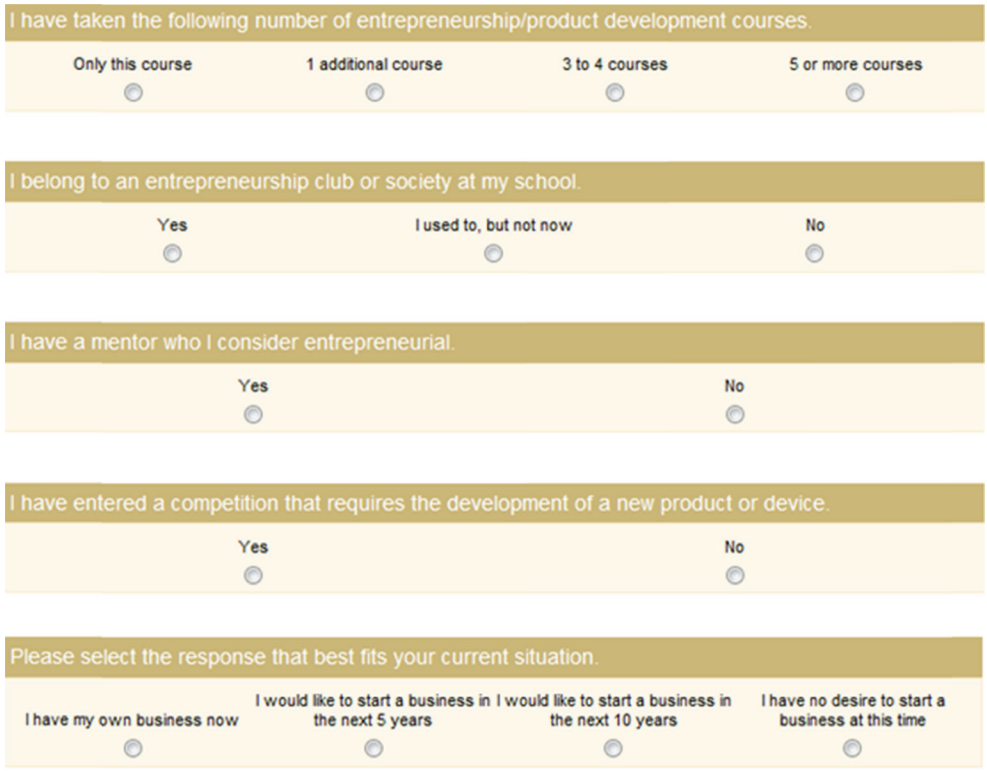

Figure 8. Student Survey Experience Questions.

of teaching entrepreneurship, indicating that entrepreneurship requires teaching both certain knowledge and skills, but also embedding particular attitudes in engineering students. Third, we find that students are surprisingly honest in their self-assessed entrepreneurship knowledge and skills compared to their instructors' intentions. Differences do exist, though, when students gain more experience in entrepreneurship. Each of these is discussed.

From the faculty perspective as measured by the EKI, it was striking to find relatively little differences between the various course types. One could argue that *Product Ideation and Development* (PID) type courses are substantially different than *New Venture Development* (NVD) and *Becoming an Entrepreneur* (BE) in that they tend to focus on design aspects from idea creation to working prototype, whereas NVD type courses tend to focus on the later part of the cycle; i.e., on bringing the prototype to market and intellectual property issues. Further, BE courses should possibly provide an overview of the entire process and focus on structure and approach as well as sales aspects. However, our results indicate that comparatively equal emphasis is placed on strategic thinking, process, structure, sales and marketing, as well as intellectual property issues across the

three course types. It would seem important to incorporate more differentiation among the various course types to provide engineering students with a full suite of entrepreneurial experiences. It is possible, with additional faculty responses, differences may be further teased out among the three course types as certain factors do have trends. As entrepreneurship becomes more valued and accepted in the engineering curricula, engineering schools need to be cognizant of the content that their courses offer, so as to provide engineering students multiple aspects of the field, as well as to "distribute" learning outcomes.

The data from the Entrepreneurship Faculty Beliefs Survey provided some interesting findings regarding instructors' perceptions of how entrepreneurship should be taught. First, consistent with a prior study of faculty beliefs (Zappe et al., 2013), most instructors felt that the skills necessary to be an entrepreneur can be taught, again not surprising given their positions. The instructors in our sample had a balanced perspective on whether courses should be attribute development versus skill-based. They believe that skills and attributes are both important in teaching entrepreneurship to engineering students. While they acknowledge that certain characteristics of entrepreneurs can more easily developed in individuals (i.e. technical skills, business skills, problem solving ability, communication skills), they are confident in their abilities that they can teach both attitudes and values as well as skills. Additionally, many instructors in our sample felt that the programs should equally focus on both teaching skills and instilling attitudes. Recognizing that teaching entrepreneurship incorporates more than just knowledge and skills and that affecting mindsets and attitudes is equally important, how these knowledge, skills and mindsets are taught or instilled may require different pedagogies. This study indicates that the types of pedagogy employed are diverse, but are also personal from the instructors' perspective. Hence, it is recommended that future research be conducted to evaluate and determine which pedagogies are most effective.

In this research, we mapped students' perceived knowledge and skills with instructors' course objectives to determine whether there were consistencies or differences. This new work complements prior work investigating differences between engineering freshmen and seniors' perceived knowledge and skills in engineering entrepreneurship (Besterfield-Sacre et al., 2012). From this last investigation, we found that students do appear to be honest in their self-assessed entrepreneurship knowledge and skills as they are statistically similar to the expectations of the faculty. As students gained entrepreneurial knowledge and skills from other courses, clubs and competitions, they notably express more self-sufficiency. This is a positive outcome; however, upon further examination, we found that overwhelmingly most engineering students enrolled in these courses had low prior exposure to entrepreneurship. Additionally, this study indicated that engineering students as a whole in these courses had proportionally lower entrepreneurship experience than their non-engineering counterparts. It is recommended that engineering schools seek both curricular and co-curricular

opportunities for engineering students to gain exposure to entrepreneurship to develop necessary knowledge, skills and mindsets.

The study does have several limitations that need to be recognized. First, the sample size of instructors is somewhat small with 25 completing the faculty survey and only 13 asking their students to complete the student EKI; though, this study involved more institutions than prior research studies. For our particular study, an active campaign was waged to solicit faculty; and a stipend for the instructor's time and effort in completing the instrument and introducing the student version in their course was offered. Even with this active recruitment strategy and incentive, we found it difficult to recruit instructors to complete the survey and to ask their students to complete the survey. The small sample size also prevented comparisons of instructor data based on characteristics such as gender, ethnicity, position held (tenure vs. non-tenure track), or discipline (business vs. engineering). While recommending that future research attempts to garner a larger sample size of instructors, we acknowledge that this would be difficult, given the strategies that we have already attempted. Perhaps one strategy might be to recruit faculty during professional conferences such as the Open conference hosted by VentureWell. Because of the small number of instructors and courses examined in this study, one needs to be cautious in generalizing beyond the sample studied. However, the types of courses examined in the study do appear to be representative of the types typically offered in engineering schools, we recognize that there could be other types of courses that are being taught in engineering schools that are not represented here. Future research may consider sampling schools engaged in the Epicenter's Pathways program.

A related limitation concerns the fact that this research represents a snapshot in time of the ecosystem in engineering entrepreneurship. The landscape of entrepreneurship courses and programs is continuously changing. Programs may shift foci; instructors in programs may change. Therefore, one needs to be cautious in generalizing this research. This is a limitation of all such studies which seek to understand current practices. However, this limitation is particularly cogent when considering engineering entrepreneurship, as the discipline is still being developed. Future research might consider longitudinal studies of a sample of programs or faculty.

To summarize, this study provides an analysis of 25 instructors from 23 unique institutions; and as such these represent roughly half of the institutions offering entrepreneurship programs within their engineering school. As mentioned in the literature, there are concerns regarding the value of teaching entrepreneurship in engineering schools. Of the instructors that did engage in the study, only 36% reported being tenured or tenured-track; hence the other two-thirds were either adjunct faculty or non-tenured stream faculty. Given the recent ASEE report, *Innovation with Impact*, it would appear that engineering schools and faculty, as a whole, do not yet value teaching entrepreneurship nor is it practiced routinely in engineering schools. Because this particular

engineering education community is still neophyte and not mainstream, it may take a while before course types and content can be clearly defined; and engaging pedagogies for both content and attitudes are fully established. Challenges related to assessment of entrepreneurship education are numerous. In general, there is a lack of consistency in learning objectives, program models, delivery modes, number and length of courses taken, and types of educational experiences that are offered. Until documentation of the nature of the learning opportunities is more fully realized (i.e., the learning objectives, pedagogy, and course content), measuring the impact of teaching entrepreneurship will remain difficult.

ACKNOWLEDGEMENTS

This research was supported by two NSF grants, EEC-0835992 and DUE-0817394. In addition, we would like to thank Ms. Naomi S. Rybeck for her assistance in data analysis.

REFERENCES

American Society for Engineering Education (ASEE). (2012). *Innovation with Impact: Creating a Culture for Scholarly and Systematic Innovation in Engineering Education*. Washington, DC: American Society for Engineering Education.

Bennett, R. (2006). Business lecturers' perceptions of the nature of entrepreneurship, *International Journal of Entrepreneurial Behaviour & Research, 12*(3), 165–188.

Besterfield-Sacre, M., Robinson, A., Ozaltin, N., Shuman, L., Shartrand, A., & Weilerstein, P. (2012). *Essential factors related to entrepreneurial knowledge in the engineering curriculum.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, San Antonio, TX.

Besterfield-Sacre, M., Ozaltin, N., Shuman, L., Shartrand, A., & Weilerstein, P. (2011). *Understanding the technical entrepreneurship landscape.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Vancouver, BC.

Bilén, S., Kisenwether, E., Rzasa, S., & Wise, J. (2005). Developing and assessing students' entrepreneurial mindset. *Journal of Engineering Education, 94*(3), 233–243.

Birmingham, W., Allison, B., & Dupree, J. (2007). *Entrepreneurship via multidisciplinary product development.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Honolulu, HI.

Carlson, L. E., & Sullivan, J. F. (2000, October). *Engineers invent and innovate*. Paper presented at the ASEE IEEE Frontiers in Education Conference, Kansas City, MO.

Charney, A. H., & Libecap, G. D. (2003). The contribution of entrepreneurship education: An analysis of the Berger program. *International Journal of Entrepreneurship Education*, 1(3), 385–418.

Creed, C. J., Suuberg, E. M., & Crawford, G. P. (2002). Engineering entrepreneurship: An example of a paradigm shift in engineering education. *Journal of Engineering Education, 91*(2), 185–195.

Dabbagh, N., & Menascé, D. A. (2006). Student perceptions of engineering entrepreneurship: An exploratory study. *Journal of Engineering Education*, 95(2), 153–163.

Duval-Couetil, N., Reed-Rhoads, T., & Haghighi, S. (2012) Engineering students and entrepreneurship education: Involvement, attitudes and outcomes. *International Journal of Engineering Education,* 28 (2), 425–435.

Duval-Couetil, N., Reed-Rhoads, T., & Haghighi, S. (2011, December). The Engineering Entrepreneurship Survey: An assessment instrument to examine engineering student involvement in entrepreneurship education. *Journal of Engineering Entrepreneurship,* 2(2), 35–56.

Falkang, J., & Alberti, F. (2001) The assessment of entrepreneurship education, *Industry and Higher Education,* 90(4), 565–570.

Henry, C., Hill, F., & Leitch, C. (2005a). Entrepreneurship education and training: Can entrepreneurship be taught? Part I. *Education + Training, 47*(2)*,* 98–111.

Henry, C., Hill, F. & Leitch, C. (2005b). Entrepreneurship education and training: can entreprenurship be taught? Part II. *Education + Training, 47*(3), 158–169.

Hochstedt, K., Zappe, S., & Kisenwether, E. (2010). *A qualitative examination of faculty beliefs related to entrepreneurship education.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Louisville, KY.

Kussmaul, C., Howe, S., Arion, D., Farris, J., Goodrich, J., Lane, P., Lehman, M., Levenburg, N., Kundrat, M., Secor, M., Twitchell, C., Way, L., & Weissbach, R. (2006, March) *Institutionalizing Entrepreneurship at Primarily Undergraduate Institutions*," Proceedings of the National Collegiate Inventors and Innovators Alliance Conference, Portland, Oregon.

Lucas, W.A., Cooper, S.Y., & Cave, F. (2009). Industry placement, authentic experience and the development of venturing and technology self-efficacy, *Technovation,* 29(11), 738–752.

Lumpkin, G. T., & Dess, G. G. (1996). Clarifying the entrepreneurial orientation construct and linking it to performance. *The Academy of Management Review, 21*(1), 135–172.

Michael, S. (2007). *What should we teach when we teach entrepreneurship?* (unpublished report). Kauffman Foundation, Kansas City, MO.

Nichols, S. P., & Armstrong, N. E. (2003). Engineering entrepreneurship: Does entrepreneurship have a role in engineering education? *Antennas and Propagation Magazine, 45*(1), 134–138.

Okudan, G. E., & Rzasa, S. (2004, October). Teaching entrepreneurial leadership: A project-based approach. Paper presented at the 34th ASEE/IEEE Frontiers in Education Conference, Savannah, GA.

Okudan, G., & Rzasa, S. (2006). A project-based approach to entrepreneurial leadership education. *Technovation, 26*(2)*,* 195–210.

Ohland, M., Frillman, S., Zhang, G., Brawner, C., & Miller, T. (2004). "Effect of an entrepreneurship program on GPA and retention", *Journal of Engineering Education, 93*(4), 293–301.

Pittaway, L., Hannon, P., Gibb, A., & Thompson, J. (2009). "Assessment practice in enterprise education", *International Journal of Entrepreneurial Behavior and Research,* 15 (1), 71–93.

Ragusa, G. (2011). *Work in Progress: Engineering creativity and propensity for innovative thinking and design in engineering students*, Paper presented at the ASEE/IEEE Frontiers in Education Conference, Rapid City, SD.

Peterfreund, A.R. (2013). Epicenter baseline survey: Report of findings. Available online at http://sagefoxgroup.com/epicenter.

Shartrand, A., Weilerstein, P., Besterfield-Sacre, M., & Golding, K. (2010). *Technology entrepreneurship programs in U.S. engineering schools: An analysis of programs at the undergraduate level.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Louisville, KY.

Shartrand, A., Weilerstein, P., Besterfield-Sacre, M., & Olds, B. (2008). *Two tools for assessing student learning in technology entrepreneurship.* Paper presented at the ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY.

Shinnar, R., M. Pruett, &Toney, B. (2009). Entrepreneurship education: Attitudes across campus, *Journal of Education for Business,* January/February, 151–158.

Smith, K.A., Sheppard, S. D., Johnson, D.W., & Johnson, R.T. (2005). Pedagogies of engagement: Classroom-based practices, *Journal of Engineering Education*, 94 (1), 87–102.

Solomon, G. T., Duffy, S., & Tarabishy, A. (2002). The state of entrepreneurship education in the United States: A nationwide survey and analysis [Electronic version]", *International Journal of Entrepreneurship Education, 1*(1), 65–86.

Standish-Kuon, T., & Rice, M. P. (2002). Introducing engineering and science students to entrepreneurship: Models and influential factors at six American universities. *Journal of Engineering Education, 91*(1), 33–39.

Sullivan, J. F., Carlson, L. E., & Carlson, D. W. (2001). Developing aspiring engineers into budding entrepreneurs: An invention and innovation course, *Journal of Engineering Education*, 90(4), 571–576.

Vesper, K. H., and Gartner, W. B. (1997). Measuring progress in entrepreneurship education, *Journal of Business Venturing*, 12, 403–421.

Wang, E. L., & Kleppe, J. A., (2001). Teaching invention, innovation and entrepreneurship in engineering. *Journal of Engineering Education*, *90*(4), 565–570.

Warren, A., Kisenwether E., & Hanke, R. (2006). *A scalable problem-based learning system for entrepreneurship education.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Chicago, IL.

Weaver, J. & Rayess, N. (2008). *Using technical entrepreneurship case studies to develop the entrepreneurial mindset in engineering students.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, Pittsburgh, PA.

Zappe, S., Hochstedt, K., & Kisenwether, E. (2012). *Faculty beliefs of entrepreneurship and design education: An exploratory study comparing entrepreneurship and design faculty.* Paper presented at the American Society for Engineering Education Annual Conference & Exposition, San Antonio, TX.

Zappe, S., Hochstedt, K., Kisenwether, E., & Shartrand, A. (2013). Teaching to innovate: Beliefs and perceptions of instructors who teach entrepreneurship to engineering students. *International Journal of Engineering Education, 29*(1), 45–62.

AUTHORS

Mary Besterfield-Sacre is an Associate Professor and Fulton C. Noss Faculty Fellow in Industrial Engineering at the University of Pittsburgh. She is the Director for the Engineering Education Research Center (EERC) in the Swanson School of Engineering, and serves as a Center Associate for the Learning Research and Development Center. Her principal research is in engineering education assessment, which has been funded by the NSF, Department of Education, Sloan Foundation, Engineering Information Foundation, and NCIIA. Dr. Sacre's current research focuses on three distinct but highly correlated areas – innovative

design and entrepreneurship, engineering modeling, and global competency in engineering. She has served as an associate editor for the *JEE*; and is currently associate editor for the *AEE Journal*, and Fellow in the American Society for Engineering Education.

Sarah Zappe is Research Associate and Director of Assessment and Instructional Support in the Leonhard Center for the Enhancement of Engineering Education at Penn State. She holds a doctoral degree in educational psychology emphasizing applied measurement and testing. In her position, Sarah is responsible for developing instructional support programs for faculty, providing evaluation support for educational proposals and projects, and working with faculty to publish educational research. Her research interests primarily involve creativity, innovation, and entrepreneurship education.

Angela Shartrand is Director of Research and Evaluation at VentureWell, a non-profit higher education network that helps emerging scientists and engineers launch products and ventures that improve life for people and the planet. Since 2005, she has contributed to the growth and development of VentureWell's entrepreneurship and innovation initiatives, which include grants, competitions, faculty development, innovator training, and network building. In addition, she has collaborated on many NSF-funded projects that are advancing entrepreneurship education in STEM fields, including Epicenter and I-Corps(tm). She and her team are currently examining the experiences of innovators who are learning how to commercialize and scale-up new technologies, products, and services, and are developing ways to assess the venture and product development status of innovation teams. She received her B.A. from Williams College, an Ed.M. from Harvard University and a Ph.D. in Applied Developmental and Educational Psychology from Boston College.

Kirsten Hochstedt is a Graduate Assistant at the Leonhard Center for the Enhancement of Engineering Education. She received her M.S. in educational psychology, with an emphasis in educational and psychological measurement, at Penn State and is currently a doctoral candidate in the same program. The primary focus of her research concerns assessing the response structure of test scores using item response theory methodology.