122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Paper ID #12723

Integrating Entrepreneurship into Capstone Design: An Exploration of Faculty Perceptions and Practices

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Abstract

Incorporating entrepreneurship into the engineering curriculum is compelling for many reasons. Entrepreneurship education has been found to boost GPA and retention rates of engineering students, provides students with the skills and attitudes needed to innovatively contribute to existing organizations and pursue their own ventures, and has the potential to address current and anticipated workforce demands.[1–3]

Entrepreneurship is taught most effectively using experiential methods.[4] Given that Capstone design courses are applied and experiential by nature, they provide an optimal context for integrating entrepreneurship into engineering education. Indeed, Ochs et al.[5] illustrated ways to integrate entrepreneurship into Capstone while simultaneously adhering to ABET standards. Shartrand and Weilerstein also identified various practices for incorporating entrepreneurship into Capstone design courses, and identified traditional and entrepreneurial Capstone elements.[6] However, it is unclear what Capstone design instructors actually practice in this area.

To better understand how and to what degree entrepreneurial elements are integrated into Capstone design classes, 225 Capstone design faculty were surveyed with an instrument designed using the entrepreneurial Capstone practices described by Shartrand and Weilerstein.[6] The survey sample included attendees of the bi-annual Capstone Design Conference, VentureWell grantees, Epicenter Pathways to Innovation team members and Pathways referrals. An explanatory multiphase mixed methods design was used involving the collection of quantitative and qualitative data. The quantitative data illustrate the extent to which faculty incorporate different entrepreneurial practices in their Capstone design courses and how important faculty believe it is to increase different entrepreneurial practices in Capstone design. The qualitative survey data provide additional insight about how faculty incorporate different entrepreneurial practices in their Capstone design courses and the challenges (perceived and actual) to implementing entrepreneurially focused Capstones. These challenges can be summarized into three overarching themes: 1) the Capstone tradition; 2) faculty exposure and experience; and 3) university culture and support. Implications, limitations, and future research are also discussed.

Keywords

Capstone, entrepreneurship, innovation, curriculum

Introduction and background

The number of STEM graduates is failing to meet current and anticipated demands in industry, technology, and the broader workforce.[3] Historically, STEM graduates have driven innovation and have been a primary source of competitive advantage for the United States.[7] Low graduation rates in STEM fields thus may ultimately compromise the position of the United States as a global leader of innovation.

Colleges of Engineering across the country and the globe are experiencing this reality. Fewer young people enroll in engineering programs than in the past, and many who do either drop out of such programs at a high rate or become dissatisfied with their career options and seek employment in other professions after graduating.[8] The 2002 report, *Engage to Excel*, indicates that increasing retention is the most efficient way to boost STEM graduates, and identifies key changes engineering faculty members can make to their curriculum and teaching to foster retention. Key is the need for intellectual and personal engagement, something often stifled by uninspiring courses and unwelcoming faculty.[7] Retention also hinges on students' ability to identify with their major and future profession, and recognition that what they are learning is aligned with the needs of their field.[3] This is a challenging prospect given the mismatch between what employers and society need from engineering graduates and engineering education.[8]

As discussed in *A Whole New Engineer*, the mismatch between engineering education and the needs of employers and society can be traced back to the publication of the 1955 Grintner report. Following the Grintner report, theoretical knowledge superseded design and practical engineering knowledge.[8] This approach made sense post-World War II when obedient engineers were hired by large organizations to focus on large-scale production. However this approach is out-of-sync with the organizations of today, large and small, which create value through the innovativeness of their workers. We must move away from the "Cold War" model of innovation, in which the government invests in the work of a small number of scientists to solve narrowly defined needs, and instead move toward a strategy that emphasizes large networks of innovators, prepared to solve the needs of many different individuals and society as a whole.[3] An approach that integrates innovation and entrepreneurship into engineering education is a practical and timely way to align the needs of employers and institutions and boost student retention.

Ohland et al. found that the integration of entrepreneurship into engineering does boost retention. Their longitudinal study revealed that those engineering students that participated in entrepreneurship education were more likely to be retained (70% vs. 51%) and claimed they were more confident in their decision to pursue an engineering degree.[1] Some of the entrepreneurship programs reviewed as part of their research revealed that while the programs differed, they also shared several features. Programs were generally available to seniors and were project based. Programs incorporated teams of students, sometimes across disciplines, working on projects supplied by industry or by the students themselves. Project outcomes typically included working prototypes and business plans. Industry, practitioners, and experienced entrepreneurs were often integrated as guest speakers, mentors, or providers of projects and internship experiences.[9]

Gilmartin et al. explain that skills fostered as part of entrepreneurship programs include, "… business understanding, an entrepreneurial mindset, understanding of technology commercialization, and/or leadership ability; some also emphasize venture creation" (p. 1).[10] Both Ohland et al. and Gilmartin et al. capture the importance of learning by doing, or an experiential approach. This type of active learning maximizes student self-efficacy and also boosts critical thinking, retention of information and persistence with the major. [4,7,11] The level of self-efficacy and engagement with the material is further enhanced when students are able to be creative and build a project around a topic that appeals to them. When students follow their passions, the passions of their teammates, or work on a topic that, for them, will make a difference in the world, their intrinsic motivation increases.[8,12] Experimentation and iteration in

the context of the project, and reflecting (in a safe environment) on the failures that ensue, completes what Neck et al. refer to as a "virtuous cycle," that equips students with confidence and knowledge that they can apply next time.[8,12]

By integrating entrepreneurship into engineering, students are likely to be more connected to their learning and thus are more likely to continue with their studies. However, students must also be able to see the relevance of their learning to their future careers. When Duval-Couetil and Wheadon interviewed engineering graduates they learned that having entrepreneurship experience on their resumes improved job prospects.[13] The students also reported that once employed, real world learning trumped knowledge and content in terms of usefulness, and of greatest use was their ability to think and solve problems. The communication skills fostered and their experiences working with teams, particularly multidisciplinary teams, were seen as critical. Also crucial was their ability to see the big picture and understand business and market implication for a project.[13]

The perspectives of these graduates aligns with employers, who indicate that communication, problem solving, and the ability to apply knowledge is essential for graduates.[14,15] Also important, but generally lacking, are effective communication and team work, the ability to understand contexts and constraints, and the ability to innovate.[14,15] All of these skills are generally addressed in entrepreneurship education. Byers et al. go further and explain, "In addition to their technical and analytical expertise, [engineers] need to be flexible, resilient, creative, empathetic, and have the ability to recognize and seize opportunities … It is thus the responsibility of engineering educators to instill these qualities in students to enable them to be more innovative and entrepreneurial" (p. 1).[2]

In addition to aligning engineering education with workforce needs, the integration of entrepreneurship can prepare students to start their own companies based on their own innovations.[11] This outcome is particularly compelling given that entrepreneurship is seen as a "potent economic force."[16] Engineering students might thus become part of the revival and re-visioning of engineers as "rock stars." (p. 72)[8] "Many electrical and civil engineers during [the late nineteenth and early twentieth century]…. were the leaders of a modern business model that featured large-scale development and world-changing inventions" (p. 74).[8] This prospect is compelling indeed for engineering graduates.

Clearly, integrating entrepreneurship education can boost retention by fostering intrinsic motivation and helping students see connections to and prepare for an exciting future career in an existing organization or as part of their own venture. When reviewing the characteristics of the entrepreneurship programs described above, one can see the similarities between entrepreneurship programs and Capstone design. As Zappe states, "Engineering Capstone design and certain entrepreneurship courses have some similarities in terms of student outcomes, course structure, and instructional methods. Both types of courses have the tendency to be less structured than traditional courses and utilize teaching methods such as problem-based or project-based learning. The role of the teacher in both areas is less likely to be a lecturer, but rather serve as a coach or a guide that assists students in completing a longer-term project" (p. 1).[17]

Many of the similarities between entrepreneurship education and Capstone design emerge from the fact that historically, Capstone design courses have been modeled around the needs of Industry and the desire to provide real-world experience for students, to better prepare them to enter the workforce.[18] Faculty teaching Capstone design view the course as a means for students to apply what they have learned throughout their undergraduate career through an open-ended design project in an environment that simulates the real world. Todd et al. observed that, "Many departments involved in Capstone-type courses believe that obtaining industry sponsored projects is an excellent way to bring industry and academia closer together" (p.171).[19] Industry support usually helps by providing viable projects and the necessary funding to give hands-on experience to students. Occasionally, such strong emphasis on industry engagement places a need for faculty themselves to have such experience or to integrate partners from industry or elsewhere who can provide insights.[20] Such a strong focus on working with industry can however restrict the course projects to solving known real-world problems in the industry, rather than focusing on creating innovative solutions and capitalizing on new market opportunity. Also, as Howe and Wilbarger have noted, the Capstone design course concept has been long reinforced by support from the Accreditation Board for Engineering and Technology (ABET).[21] This may also dissuade faculty from swaying from the traditional, industry-focused Capstone design course model.

The Capstone design course curriculum, however, is witnessing change, with focus increasing on tight integration between courses and projects and an emphasis on issues such as engineering ethics and project management.[20] Some schools of engineering have started to offer blended Capstone design courses where engineering students work closely with team members from other disciplines, including business students. For example, Archibald et al. presented on a program offered at the Grove City College, which focused on teaching entrepreneurial skills to engineering students in a hands-on product development environment that mimicked the real world.[22] Ochs et al. also provided a case study illustrating how entrepreneurship can be integrated into Capstone design while also exceeding ABET standards.[5]

Purpose and research questions

While the literature documents examples of entrepreneurially focused Capstones, it is unclear how prevalent these courses are at U.S. institutions and to what extent they integrate different entrepreneurial education practices. The purpose of this research is to examine the prevalence of different entrepreneurially focused curricular practices of engineering Capstone design faculty. The two primary research questions for this study are:

Research Question 1: How and to what extent do faculty incorporate different entrepreneurial practices in their Capstone design courses?

Research Question 2: How important is it to increase different entrepreneurial practices in the Capstone design class?

Methods

An explanatory sequential mixed methods design, paired with multiphase combination timing, was used for this study.[23] This process involves the collection and analysis of quantitative data,

concurrent with and then followed by the collection and/or analysis of qualitative data. The rationale for combining and integrating quantitative and qualitative data is that neither is sufficient on its own to capture the information necessary to answer the research questions.

A brief online survey was created to gather data about both research questions 1 and 2. The survey questions were designed to capture entrepreneurially focused Capstone practices identified by Shartrand and Weilerstein (see Appendix B).[6] The survey also drew from the "importance" versus "practice" framework used in the National Survey of Engineering Faculty Committees, Department Chairs, and Deans described in ASEE's *Innovation with Impact* report.[24]

Participants were contacted by email. The email invitation included a brief description of the study and served as the consent form. Participants who agreed to participate followed a link to the online survey. The survey was emailed to faculty through the following recruitment strategies: 1) the email addresses for all faculty on the on mailing list of the bi-annual Capstone Design Conference (last held June 2-4, 2014 in Columbus, Ohio) were located and email invitations to participate in the survey were sent to them (161 faculty); 2) email invitations were sent to the PIs that applied, during the last five years, for VentureWell Course and Program grants to develop more entrepreneurially focused Capstone courses (57 faculty); 3) an email request was also sent to Epicenter Pathways to Innovation teams to help identify faculty who taught engineering Capstone design (52 faculty). Epicenter Pathways to Innovation teams are teams of faculty that are part of the NSF funded Epicenter Pathways to Innovation program who are actively working to integrate entrepreneurship and innovation into undergraduate engineering education.

Table 1. Survey Population

Group 1	Faculty on the Capstone design mailing list who are also either (i) VentureWell members, (ii) VentureWell conference attendees.	Distributed to 107 62 responses 58% response rate
Group 2	Capstone design mailing list faculty with no VentureWell affiliation	Distributed to 47 29 responses 62% response rate
Group 3	VentureWell grant applicants	Distributed to 56 17 responses 30%, response rate
Group 4	Pathways faculty referrals	Distributed to 41 29 responses 71% response rate
Group 5	Pathways faculty	Distributed to 1 1 response 100% response rate

Survey recipients were placed into five groups listed in Table 1; each group received a custom email invitation that closely reflected their affiliations and interests. Contact information was entered into Limesurvey, an open source online survey tool.[25] This list was de-duplicated in the order in which each contact was entered, resulting in a list of 252 faculty members. Email invitations were sent on January 5, 2015 and participants received a maximum of four reminders. Four reminder emails were sent between January 6 and 14.

Quantitative and qualitative data were integrated during the design, collection, and analysis phases of the study. Analysis of the closed-ended response items from the 21-item, *2015 Current Capstone Practices and Entrepreneurship* survey were collected from 138 faculty members (see Table 1), revealed an overall response rate of 55% with an adjusted response rate of 49% (n = 111) after accounting for respondents who indicated they were "not" teaching Capstone design.

Quantitative data indicated the extent to which respondents had integrated entrepreneurship into their Capstone design courses, and the degree to which they felt it was important to increase entrepreneurship in Capstone design. Qualitative data came from a single open-ended survey item, which asked respondents to "share any other thoughts about integrating entrepreneurship into engineering Capstone design courses." Fifty-six respondents completed this item (item-level response rate = 40%). The purpose of analyzing open-ended feedback was to explore how faculty members had integrated entrepreneurship into their Capstones and identify additional themes that could be used to explain faculty practices in greater depth. Detailed descriptions of the phase one (quantitative) and phase two (qualitative) analytical approaches are provided below.

Analysis

Quantitative analysis

The quantitative survey data was used to answer research questions 1 and 2. All quantitative data were analyzed using descriptive statistics in SPSS. Excel was also used to aggregate data and create descriptive charts and tables. Tables and charts are presented to highlight results and show the distribution of the aggregate data as well as the means. The researchers chose to display the distribution in addition to the means to show the spread of the data.

Qualitative analysis

All open-ended responses were entered into Microsoft Excel as matrix displays, and were pattern coded using thick description and anonymous quotes to reduce bias.[26] Codes were assigned to 'chunks' of data (phrases, sentences or paragraphs) that conveyed a meaningful idea or set of ideas.[27,28] Data were further analyzed for common and divergent themes and as new themes emerged the data were partitioned and coded through an iterative process. A codebook with three sections: codes, definitions and examples, was developed to guide the analysis.[28] Codes were used to develop high-level categories, and themes until the point of saturation (i.e., when additional analysis no longer contributes to the discovery of new information).[29] Content analysis revealed four high-level categories and multiple themes. Each response was assigned at least one code, theme, or category, and more were added when necessary. Table 2 presents category definitions and frequencies. For all themes, only the most common are discussed within each category. Although themes with two or fewer coded responses were recorded, for the purposes of this study, only codes that represent greater than or equal to 5% (3 out of 56) of all responses are discussed.

Table 2. Category, Definition, and Frequency		
Category	Definition	Frequency
Challenge	Applies to any faculty perceived and/or realized obstacles associated with integrating entrepreneurship into Capstone design	27
Strategy	Refers to particular methods and approaches Capstone faculty have taken to 1) integrate entrepreneurship into their Capstone design course OR 2) expose students in their Capstone course to entrepreneurship	21
Opinion	General perceptions on the topic of integrating entrepreneurship into Capstone design.	15
Other	Any comments that could not be classified into the above categories	7

Results

Quantitative results

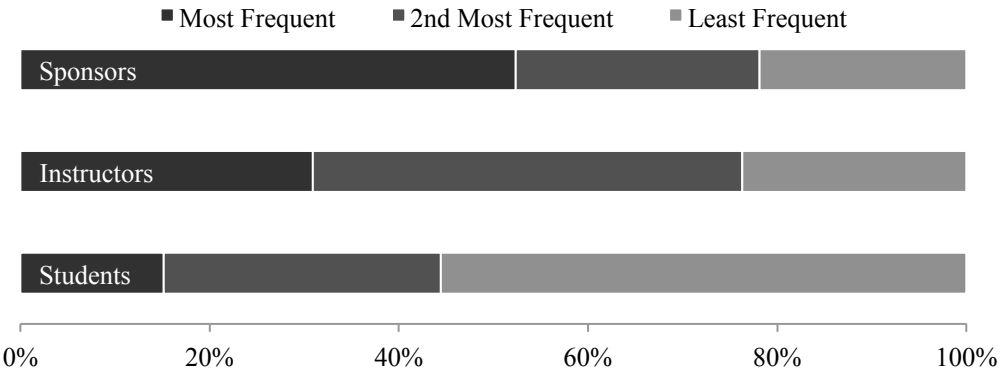
Demographics

Most survey respondents were male (80%, n = 87) and were in the field of engineering (93%, n = 103). The most popular engineering sub-discipline was mechanical engineering (50%, n = 51) (See Appendix Tables A1-A3).

Project identification and formulation

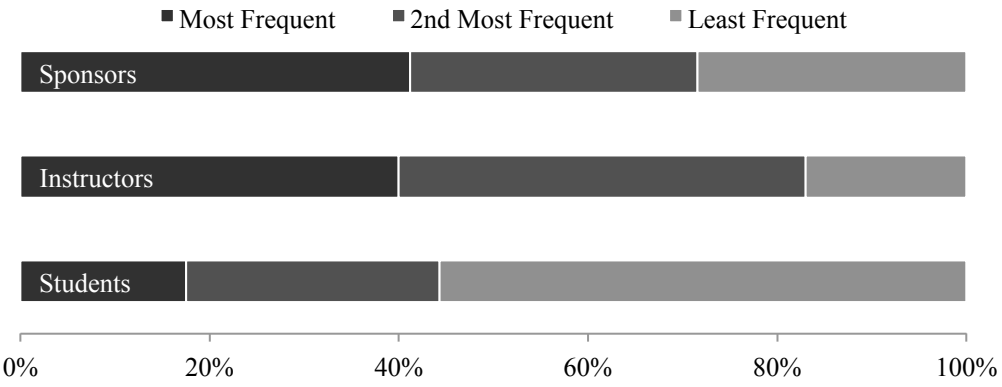
Survey respondents indicated that sponsors (55%, n = 57) and instructors (44%, n = 43) most frequently defined Capstone design project ideas (Figure 1). Similarly, sponsors (42%, n = 44) and instructors (43%, n = 43) most frequently defined problem scope (Figure 2). However, 15% of respondents said students most frequently initiated Capstone design project ideas and 17% said students defined the problem scope most frequently (see Figures 1 & 2 below).

Figure 1. What group most frequently initiates Capstone design project ideas? Please rank the following list from most frequently (1st) to least frequently (3rd).



Note. Item level response rate varied by construct. Rates ranged from 84% to 94% (93 to 104 of 111). Percentages are rounded to the nearest whole number.

Figure 2. What group most frequently defines the problem scope of Capstone design projects? Please rank the following list from most frequently (1st) to least frequently (3rd).



Note. Item level response rate varied by construct. Rates ranged from 84% to 94% (93 to 104 of 111). Percentages are rounded to the nearest whole number.

Course and project funding practices

Almost half of the respondents said that only "a few" (43%, n = 48) of their Capstone projects were sponsored by a specific industry sponsor, while 14% (n = 3) said that "none" were. In the same vein, while about a third of respondents (27%, n = 30) indicated that "a few" industry sponsors provided unrestricted gifts to support the entire Capstone courses almost half (45%, n = 50) said industry sponsors provided no such gifts (See Table 3).

Table 3. Project Funding

Question	n	Mean	None (1)	A few (2)	Half (3)	Most (4)	All (5)
Projects are funded by industry sponsor	111	2.78	13%	43%	12%	18%	14%
Industry sponsors provide unrestricted gifts to support the entire course	111	2.04	45%	27%	14%	6%	7%

Note. Item level response rate: 100% (111 of 111). Percentages are rounded to the nearest whole number.

Criteria for project success and course requirements

The vast majority of respondents (94%, n = 104) reported that the success of the final project is evaluated by the degree to which it meets technical requirements "often" or "always." Likewise, most respondents indicated that success was evaluated "often" or "always" according to whether projects met end user and/or customer needs (86%, n = 96) and sponsor needs (73%, n = 80).

Similarly, while most (84%, n = 93) respondents indicated that a working prototype in their Capstone design course is "often" or "always" required, only half said a customer-validated solution was (51%, n = 57). Over half of respondents indicated their Capstone courses "rarely" or "never" require business model or commercialization plans (63%, n = 70) or assessments of market size (54%, n = 60). At the same time, students are "often" or "always" encouraged to use failure to iterate on their project designs (56%, n = 62), an educational practice which appears to

be consistent with the emphasis on meeting technical requirements and developing working prototypes (see Table 4).

Table 4. Criteria for Project Success and Course Requirements

Question	Item	n	Mean	Never (1)	Rarely (2)	Some-times (3)	Often (4)	Always (5)
To what extent is the success of the final project/product evaluated by the following:	Meeting technical requirements	111	4.62	0%	1%	5%	24%	69%
	Meeting end user and/or customer needs	111	4.29	1%	4%	9%	39%	48%
	Meeting sponsor needs	110	4.03	5%	7%	15%	25%	48%
How often are the following required in the course?	Working prototype	111	4.26	5%	4%	7%	27%	57%
	Customer-validation of solution	111	3.39	6%	22%	21%	30%	22%
	Assessment of market size	111	2.53	20%	34%	27%	11%	8%
	Business model or commercialization plan	111	2.26	30%	33%	23%	10%	5%
How often is "Failing forward" (using failure to iterate the design) encouraged?		110	3.61	4%	17%	23%	27%	29%

Note. Item level response rate varied by construct. Rates ranged from 99% to 100% (110 to 111). Percentages are rounded to the nearest whole number.

Project duration and extended support

Most respondents (55%, n = 61) indicated that student projects sometimes continue after the course ends, though about a third said this occurred "rarely" or "never" (31%, n = 34). Likewise, nearly half said that students pursue work from a prior semester "sometimes" (49%, n = 54), but about the same number said this took place "rarely" or "never" (47%, n = 52) (See Table 5). Sixty percent (n = 67) of respondents indicated that their institution has infrastructure in place to support students who develop their projects beyond the course (See Table 6).

Table 5. Project Duration

Question	n	Mean	Never (1)	Rarely (2)	Some-times (3)	Often (4)	Always (5)	I don't know
How often do projects continue when the course is complete?	111	2.71	2%	29%	55%	12%	0%	3%
How often do students pursue prior work?	111	2.50	9%	38%	49%	4%	1%	--

Table 6. Does your institution have infrastructure to support students who develop their projects beyond the course?		
Answer	Count	Percentage
Yes	67	60%
No	26	23%
Uncertain	18	16%
Note. Item level response rate: 100% (111 of 111). Percentages are rounded to the nearest whole number.		

Intellectual property

Respondents said they include intellectual property (IP) protection as part of their Capstone design course curriculum "often" or "always" (64%, n = 71). Most respondents (70%, n = 77) also indicated that students are able to own the IP that they create during their Capstone design course. Thirty-nine percent of respondents (n = 43) indicated that students are "rarely" or "never" required to sign an exclusive license agreement (see Table 7) and 70% (n = 77) said that students can own intellectual property they create during Capstone design courses (Table 8).

Table 7. Student IP							
Question	n	Mean	Never (1)	Rarely (2)	Some-times (3)	Often (4)	Always (5)
How often is IP protection part of the course curriculum?	111	3.72	8%	18%	10%	22%	42%
For sponsored projects, how often are students required to sign an exclusive license agreement with the sponsor?	109	2.95	15%	25%	27%	18%	16%
Note. Item level response rate varied by construct. Rates ranged from 98% to 100% (109 to 111). Percentages are rounded to the nearest whole number.							

Table 8. Can students own intellectual property that they create during the Capstone design course?		
Answer	Count	Percentage
Yes	77	70%
No	20	18%
Uncertain	13	12%
Note. Item level response rate: 99% (110 of 111). Percentages are rounded to the nearest whole number.		

Importance of educational outcomes

Most respondents indicated that competence in educational outcomes such as teamwork (97%, n = 108) and technical competence (95%, n = 105) were "important" or "very important" for their Capstone design course. Alternatively, educational outcomes such as understanding pathways to technology commercialization (52%, n = 58) and the ability to recognize market opportunities (43%, n = 48) were "of little importance" or "unimportant" (see Table 9).

Table 9. Please rate the importance of the following educational outcomes for your Capstone design course							
Item	n	Mean	Un-important (1)	Of Little Importance (2)	Moderately Important (3)	Important (4)	Very Important (5)
Technical competence	111	4.59	0%	0%	5%	30%	65%
Competence in team work	111	4.70	0%	0%	3%	24%	73%
Ability to recognize market opportunities	111	2.77	11%	32%	32%	19%	6%
Understanding pathways to tech commercialization (e.g., licensing, ventures)	111	2.53	13%	40%	32%	13%	3%
Note. Item level response rate: 100% (111 of 111). Percentages rounded to the nearest whole number.							

Importance of entrepreneurial support: In Capstone design

Most respondents felt as though it was important or very important to increase the degree to which understanding IP (58%, n = 63) and customer validation (57%, n = 62) were supported in their Capstone design classes. On the other hand, respondents felt that increasing the degree to which the business model or commercialization plan (46%, n = 49) or the assessment of market size (40%, n = 43) in their Capstone design course were of little to no importance. Respondents were relatively evenly divided with respect to the importance of student-sponsored projects. Forty-four percent (n = 47) felt that that supporting student-sponsored projects was important or very important; 45% (n = 50) felt that it was important or very important to have infrastructure to help students continue to develop their project once the course ends (See Table 10).

Table 10. In your opinion, how important is it to increase the degree to which the following are supported in your Capstone design class							
Item	n	Mean	Un-important (1)	Of Little Importance (2)	Moderately Important (3)	Important (4)	Very Important (5)
Student sponsored projects	107	3.15	14%	22%	21%	23%	21%
Customer validation	108	3.68	4%	6%	32%	33%	24%
Assessment of market size	108	2.81	16%	24%	32%	19%	9%
Business model or commercialization plan	107	2.64	21%	25%	30%	19%	6%
Understanding of intellectual property	108	3.72	2%	6%	33%	34%	24%
Infrastructure to help students continue to develop their project once the course ends	109	3.21	10%	22%	22%	28%	17%
Note. Item level response rate varied by construct. Rates ranged from 96% to 100% (107 to 111). Percentages are rounded to the nearest whole number.							

Importance of entrepreneurial support: Broadly on campus

Most respondents (59%, n = 61) said it was important to increase campus infrastructure to help students continue developing their projects once the course ends. Most respondents also felt it was important to increase the degree to which understanding of IP was supported more broadly on their campus (57%, n = 59) (See Table 11).

Table 11. In your opinion, how important is it to increase the degree to which the following are supported broadly on your campus?

Item	n	Mean	Un-important (1)	Of Little Importance (2)	Moderately Important (3)	Important (4)	Very Important (5)
Student sponsored projects	103	3.32	12%	12%	30%	26%	20%
Customer validation	103	3.29	8%	12%	37%	31%	13%
Assessment of market size	103	3.06	12%	18%	34%	24%	12%
Business model or commercialization plan	102	3.25	10%	11%	37%	28%	14%
Understanding of intellectual property	103	3.63	6%	7%	30%	33%	24%
Infrastructure to help students continue to develop their project once the course ends	103	3.64	6%	13%	22%	30%	29%

Note. Item level response rate varied by construct. Rates ranged from 92% to 100% (102 to 111). Percentages are rounded to the nearest whole number.

Qualitative Results

Content analysis revealed four high-level categories: Opinion, Challenge, Strategy and Other. Several sub-themes within each category were also identified (Table 2). The Opinion, Challenge and Strategy categories are reviewed here.

Opinion

In alignment with quantitative findings, most Opinion category statements acknowledged explicitly the importance of integrating entrepreneurship into engineering education (n = 10). Half of these statements, however, were coupled with statements that expressed concern about the challenges facing Capstone design faculty. Table 12 lists the most common themes for the Opinion category. Eighteen percent (n = 10) of all Opinion category responses were coded into the theme *entrepreneurship is important*. No other Opinion category responses exceeded 5% representation.

Table 12. Opinion Themes: Definition, Examples and Frequency	
Definition	Examples
	Theme 1: Entrepreneurship is important (n = 10)
Recognizing the importance of incorporating entrepreneurship into Capstone or engineering education more broadly	"I think it is very important that our undergrads have tangible entrepreneurial and intrapreneurial skills upon graduation. The diversity of thought and persistence required to be a successful entrepreneur are invaluable assets for our graduates to carry forward--regardless of whether they go to work for a Fortune 500 company, a consulting firm, Wall Street, or start their own ventures. It would be fantastic if our graduates all had an ability to recognize an opportunity, create viable solutions, and articulate a value proposition that provides a unique, economically sustainable product or service" "I think it is important for students to learn entrepreneurial awareness and competences, but I am not convinced that the Capstone class is the best place to do this in my particular program." "Entrepreneurship is an essential part of engineering design course. In industrial perspectives (who students will eventually land on the jobs), engineers are more or less involved in business and revenue of the organization that he or she works."
Note. Open-ended responses were corrected for spelling where appropriate.	

Challenge

The Challenge category was reserved for responses pertaining to actual and/or perceived challenges associated with integrating entrepreneurship into Capstone design. Table 13 lists the most common themes for the Challenge category. Eighty one percent (n = 22) of all Challenge category responses were coded into one or more of the six themes below, arguing that entrepreneurship integration was either challenging due to lack of support, or inappropriate for Capstone design. Faculty who said support for this approach was lacking cited two principle barriers including: 1) *insufficient resources* in terms of funding and faculty; and 2) *inappropriate timing* (Capstone is too late; students need to be exposed to entrepreneurship earlier in their academic career). In addition, not all respondents were convinced that integrating entrepreneurship into Capstone was appropriate, citing several concerns: 1) *limited relevance* (entrepreneurship does not make sense for all engineering disciplines, e.g., civil engineering); (2) *low demand* (most engineering students just want jobs); 3) *different focus* (Capstones are about forming relationships with industry) and 4) *competing tradeoffs* (compromising coverage of the core curriculum). Illustrative quotes are provided below the table in support of the coding scheme.

Table 13. Challenge Themes: Definition, Example and Frequency	
Definition	Examples
Theme 1: Resources (n = 5)	
Funding or resource (i.e., faculty training) constraints make integrating entrepreneurship into Capstone a challenge. Dependence on industry sponsorship is a challenge for integrating entrepreneurship into Capstone design	"Because we have industry funded projects in Capstone, we do not teach entrepreneurial models in this course…" "I feel this is very important for our engineering Capstone courses, but it requires support and resources for engineering profs who have little experience in many of these topics and application. It is also difficult to fund entrepreneurial projects"

Table 13. Challenge Themes: Definition, Example and Frequency	
Definition	Examples
Theme 2: Relevance (n = 5)	
Relative importance of integrating entrepreneurship into Capstone design varies by discipline	"Capstone projects are very different in disciplines where a prototype is possible vs. not possible (i.e. building a dam)." "Entrepreneurship in a civil engineering is not an easily integrated concept. We do not generate prototypes and very seldom generate patentable designs. We typically cannot produce a legally buildable design as a P.E. must stamp the drawings. Faculty cannot do this as the University does not have liability insurance. Civil projects are typically large in size and company ownership is not possible until at least 4 years post-graduation when an engineer obtains their P.E. license."
Theme 3: Low demand (n = 4)	
Entrepreneurship appeals to a subset of the broader engineering student body; recognize that not all students are looking to become entrepreneurs or want to learn about entrepreneurship	"The majority of students are not able or do not want to define, scope, and commercialize. How do we target the ones who do? Probably not through required courses like mine." "Need a balanced course as not all students will become entrepreneurs. Some just need to check the box to complete first degree so as to follow next degree or other careers."
Theme 4: Timing (n = 3)	
Entrepreneurship needs to be included earlier in the curriculum as opposed to OR in addition to Capstone	"While entrepreneurship is important, I strongly believe it has to be encouraged from early stages, and not only at the last semester." "Capstone, i.e., senior design is too late to start talking about entrepreneurship. We would like freshmen to do a business plan."
Theme 5: Focus (n = 3)	
Capstones should focus on fostering government / industry relationships or conducting research	"There are other courses that would be more appropriate. Our current Capstone course is not where this belongs. We want to give students the challenge of working on industry sponsored projects for professional and customer purposes. Entrepreneurship can be covered in other project courses…" "I think it is important for students to learn entrepreneurial awareness and competences, but I am not convinced that the Capstone class is the best place to do this in my particular program. I rely on the Capstone course to provide students connection with industry/government, and with currently practicing engineers, something that is harder for them to do on entrepreneurial projects. I have had entrepreneurial projects in the past, but prefer to work with externally sponsored projects now."
Theme 6: Tradeoffs (n = 3)	
Adding another topic into Capstone design (i.e., entrepreneurship) means sacrificing time that could be spent on other topics / experiences and/or compromising the quality of the topics covered in the class (including entrepreneurship).	"The biggest problem with integrating entrepreneurship into Capstone is the understanding that one has only so much time to do any subset of tasks, and there are trade-offs to doing all the different aspects well. Most programs want to say they do 'All of the above' -- but that means 'all of the above' are likely to be mediocre, and in the end, not very realistic..." "I am a strong supporter of entrepreneurship and have had past Capstone teams carry their project forward after graduating. However, there are serious issues with making it the focus of the Capstone class. Specifically, as an engineer we need to grade on technical competence and design ability not the business plan, marketing, and fundraising that is necessary when starting a small business. Our current setup is not conducive for entrepreneurship because students don't have the space to work on ideas, the access to equipment, or seed funding to cover costs."
Note. Open-ended responses were corrected for spelling where appropriate.	

Strategy

The Strategy category focuses on the different approaches faculty members use to 1) integrate entrepreneurship into their Capstone design courses or 2) expose students to entrepreneurship outside of Capstone design. The most common themes for the Strategy category appear in Table 14.

Eighty-one percent of Strategy category responses were coded into one or more of the six themes below (n = 17). Several responses in this category were from faculty who had 1) already integrated entrepreneurship into their Capstone course, or were actively planning to do so (n = 5); or 2) were aware of other entrepreneurship opportunities available to students. Faculty who had already begun integrating entrepreneurship or who were planning on doing so, articulated the following strategies: 1) promoting *multi-disciplinary* student teams; 2) *developing* or re-developing new courses to accommodate entrepreneurship; 3) *exposing* students to entrepreneurship through lectures, or experiential learning opportunities (e.g. competitions) and 4) forming *partnerships* with other departments. Although these four themes accounted for the majority of strategies employed to integrate entrepreneurship into Capstone courses, faculty also sought out other ways to meet this need. They accomplished this by referring students to *other courses* or programs that targeted students interested in venture creation. Venture creation, and more specifically the distinction between venture creation and the entrepreneurial mindset, was explicitly mentioned by at least two respondents; prior research has demonstrated that this distinction is of great importance for better understanding how entrepreneurship is being integrated in engineering education.[10] Themes and examples are provided in Table 14 for additional clarity.

Table 14. Strategy Themes: Definition, Examples and Frequency	
Definition	Examples
Theme 1: Future Plans (n = 5)	
Identified plans to integrate entrepreneurship into Capstone design at a later date	"We hope at some point to integrate entrepreneurship into engineering Capstone design particularly through collaboration with our business school. We have begun utilizing an innovative canvas tool to get students to think along the lines of market value and scalability of their solutions. "We are making a change in the upcoming academic year to include other students who are members of design teams but who are not engineering students in the Capstone design course"
Theme 2: Other courses (n = 4)	
Other courses (outside of Capstone) integrate entrepreneurship principles and expose students to entrepreneurship.	"At [our institution] all students engage in a foundational entrepreneurship course and we have structures to support student entrepreneurship (including students owning all of their IP except in the case of Capstone projects where sponsors retain it, ~80%)." "We have complimentary management of technology courses that cover entrepreneurship, project management, etc. so it is more important to bridge connections to those courses and leverage resources on campus like venture creation courses in the college of business that would allow students to work with those from other disciplines"
Theme 3: Multi-disciplinary student teams (n = 4)	
Promote integration of entrepreneurship in Capstone design through the formation of multidisciplinary student teams	"We have brought in Business students to work with our engineering students on the teams. Usually 1 Bus student per 3-4 Eng students…" "We are making a change in the upcoming academic year to include other students who are members of design teams but who are not engineering students in the Capstone design course"

Table 14. Strategy Themes: Definition, Examples and Frequency	
Definition	Examples
Theme 4: Course (re-) development (n = 3)	
Modify existing courses and/or developing new ones to accommodate integrating entrepreneurship into Capstone design	"We are working to launch a new joint Capstone course between the college of engineering and college of business that is focused on student initiated projects…" "Entrepreneurship has been a relatively small part of the ME Capstone Design course to this point (a number of years)" "A new supplemental elective design course (in addition to the required Capstone Design courses) with more emphasis on entrepreneurship has been added this semester by me. It is too early (four class meetings) to make any substantive comments about how it is going to work. I have high hopes..."
Theme 5: Exposure (n = 3)	
Promote integration of entrepreneurship in Capstone design by exposing students to real-world entrepreneurs, investors or via experiential learning (i.e., product invention competitions etc.)	"Nice idea, we have guest lectures from students who have gone on to form their own companies, we have lectures about how to start a company (business plan, etc.)…" "…So our vision is to have the corporate sponsor communicate how their company and culture foster entrepreneurship and the "stresses" that accompany entrepreneurship at the same time as pushing out product to pay the bills. We are new to corporate sponsored engineering Capstone, and are seeing more students appeal the corporate sponsored projects in lieu of their projects. Our hope to try to match a volunteer corporate mentor that can mentor students in real-world entrepreneurship applications. We hope to see more examples of this over the next few years."
Promote integration of entrepreneurship in Capstone design by exposing students to real-world entrepreneurs, investors or via experiential learning (i.e., product invention competitions etc.)	"Nice idea, we have guest lectures from students who have gone on to form their own companies, we have lectures about how to start a company (business plan, etc.)…" "…So our vision is to have the corporate sponsor communicate how their company and culture foster entrepreneurship and the "stresses" that accompany entrepreneurship at the same time as pushing out product to pay the bills. We are new to corporate sponsored engineering Capstone, and are seeing more students appeal the corporate sponsored projects in lieu of their projects. Our hope to try to match a volunteer corporate mentor that can mentor students in real-world entrepreneurship applications. We hope to see more examples of this over the next few years."
Theme 6: Partnerships (n = 3)	
Faculty form relationships with other departments to integrate entrepreneurship into Capstone.	"...I'm starting to work with someone in the Business College to see if we can integrate business plans more where they make sense…" "I also partner with faculty from other departments to allow engineering students to obtain experience in those disciplines and vice versa. A number of students have gone on to participate in bplan challenges and innovation challenges."
Note. Open-ended responses were corrected for spelling where appropriate.	

Discussion

The findings of this study raise several interesting issues. First, while many faculty expressed an interest in integrating entrepreneurship into Capstone design, which could indicate an awareness of the benefits of said integration, most continue to engage students in what Shartrand and Weilerstein describe as a more traditional Capstone approach.[6] Faculty consider meeting technical requirements and developing a working prototype to be a more important educational outcome than understanding market size, or developing business plans and commercializing technologies. Providing students with the infrastructure and support needed to pursue their project can help ensure that students have sufficient time to for idea generation, validation, and

product development. It also increases the likelihood that students will continue to build on early successes and pursue their product or venture.[6] Survey responses show that in most instances, sponsors are providing project ideas and sponsors or instructors are defining the project scope. However, some Capstone faculty have successfully incorporated a few entrepreneurship principles such as failing forward, meeting customer needs, and intellectual property (IP) into their Capstone design courses. Yet, many respondents indicate a currently unrealized desire to increase the degree to which entrepreneurship is integrated.

Faculty surveyed said that the broader campus can foster these efforts and support integration more effectively by increasing the infrastructure that supports students who want to develop their projects outside of class, incorporating student-sponsored projects, and increasing student knowledge of IP, business models and commercialization. Support can also be provided by ensuring that entrepreneurial skills and knowledge are imparted to students earlier in their academic career because respondents felt that teaching students about entrepreneurship in their senior year is simply too late.

The desire for broader campus support to foster the integration of entrepreneurship may be impeded by the important historical role Capstone design has played in preparing students for work in industry. Faculty continue to feel the need to reinforce prior technical learning and satisfy industry sponsors. This close connection with industry also provides funding and perceived constraints come with said funding. If industry is the primary source of funding for projects in a Capstone design course, the prospect of losing said funding might preclude faculty from integrating student-driven projects.

Some faculty do not feel there is enough room to incorporate more content into their courses and other don't feel equipped to teach entrepreneurship; training is needed on how to teach entrepreneurship into Capstone, without sacrificing what is considered core content. Some also believe entrepreneurship may not be appropriate for all students. In civil and chemical engineering, for example, students typically design infrastructure projects or chemical manufacturing processes. These projects are not ones that students can easily spin off into a venture. Some faculty also had concerns that since not all students are interested in becoming entrepreneurs or starting their own businesses, a required Capstone design course may not be the best vehicle for introducing these skills. In spite of these perceived challenges, some faculty are currently planning to integrate entrepreneurship into their Capstone design courses, and some are already successfully doing so. For these faculty, entrepreneurship is not simply about preparing students to launch a venture; it is also about better equipping students to be "intrapreneurs" who innovatively contribute to existing organizations.

Open-ended responses suggest that a good number of Capstone design faculty feel that it is important to expose students to entrepreneurship before they participate in Capstone. Integrating faculty and students from other disciplines, particularly business and the cross-pollination of expertise that provides, is also deemed essential. Faculty have also found ways to overcome discipline-specific challenges, for example, by starting to develop "products with prototypes" in the context of a chemical engineering class. Others do not see the integration of entrepreneurship as detracting from or reducing traditional Capstone design content; they do however note that the inclusion of entrepreneurship motivates students.

Conclusion

While most faculty surveyed said it is important to increase entrepreneurship elements in their classes and on their campuses, results indicate an approach to implementation that is more conservative. The data indicate that faculty members utilize a wide range of implementation efforts to incorporate entrepreneurship into their Capstone design courses. The more widely adopted practices, like using failure to iterate on a design, fall comfortably within the traditional domain of Capstone with its focus on design and industry. Less frequently adopted practices such as student-sponsored projects, assessment of market size, and the development of a business or commercialization plan fall outside the bounds of the traditional Capstone model and thus may be more challenging to implement. The open-ended responses provide insights into how and why implementation practices varied greatly among faculty. When the open-ended responses are combined with the quantitative results, topics emerge that start to capture the perceived challenges encountered when implementing entrepreneurially focused Capstones. These topics can be characterized as falling into three distinct, but connected groups: the Capstone tradition, faculty exposure and experience, and university culture and support.

The Capstone tradition

Traditionally, Capstone design courses have focused on connecting and preparing students for work through the assignment of industry-sponsored projects. Funding for these projects is provided by industry, and this approach has long been supported by ABET. Moving away from a successful, ABET approved, funded model is challenging. For change to happen, fundraising models to support student-driven projects, and strategies for designing entrepreneurially focused Capstones that meet ABET standards should be shared.

Faculty exposure and experience

Faculty members who are able to implement more entrepreneurially focused Capstones are aware of the notion that entrepreneurship and entrepreneurial experiences encompass more than starting ventures. As discussed by Gilmartin et al., venture creation is only one of the skills entrepreneurship education may foster.[10] Frequently, programs and courses focus on the development of entrepreneurial mindset, as well as business and leadership skills. Such experiences thus prepare students to make important contributions to existing organizations (intrapreneurship). Implementation of more entrepreneurially focused Capstones may be increased if faculty members are exposed to these broader definitions of entrepreneurship, are introduced to models of successful implementation, and are informed about how these approaches boost students' intrinsic motivation. To successfully integrate entrepreneurship, faculty must also have entrepreneurial experience, professional development training, or the ability to collaborate with faculty members on campus who are willing to bring their entrepreneurial experience into the engineering classroom.

University culture and support

As discussed above, if faculty members lack the expertise to teach entrepreneurship in their Capstone design classes, collaborating with more experienced faculty members on campus could be one solution. However, such collaborations are only possible if the university has a culture that supports efforts to maximize entrepreneurship education outcomes. As one respondent put it,

"The boldness to be innovative and entrepreneurial needs to become a culture." When entrepreneurship is a part of the culture, faculty members are more likely to collaborate with other experienced faculty, thereby develop a broader understanding of entrepreneurship and what it can look like in an educational setting. Faculty members may similarly be supported in their efforts to create more entrepreneurially focused Capstones through investment in university infrastructure, professional development, or assistance with funding of students projects. An entrepreneurially focused institution will also provide multiple entrepreneurial experiences that students can take advantage of throughout their academic careers, providing the scaffolding needed to succeed in a more entrepreneurially focused Capstone.

Limitations and future research

The survey as designed generated significant insights into how and to what extent faculty members incorporate different entrepreneurial practices, and revealed some of the perceived challenges face when preparing to integrate entrepreneurship. Still, one primary limitation exists: 74% of respondents are affiliated with VentureWell and Epicenter's Pathways to Innovation program, which focus directly on fostering entrepreneurship education. Therefore, the study findings may not be generalizable to the full population of institutions. However, the practices discussed in this study illustrate that given the right context and conditions, motivated faculty can innovatively integrate entrepreneurship into Capstone design. Also, as part of the third and final phase of this study, the authors have begun interviewing survey respondents using stratified purposeful sampling,[30] in order to provide deeper insights into survey results. This feedback, together with further analysis of how VentureWell and Epicenter affiliated Capstone design instructors and their institutional contexts differ from other non-affiliated Capstone design instructors, will help us understand how entrepreneurship can be more broadly integrated into Capstone Design and how institutions can best support faculty in these efforts.

Acknowledgements

This work is supported by the National Science Foundation (DUE 1125457) and the Lemelson Foundation. The authors would also like to thank Susannah Howe for her generous insights in the design and distribution of the survey instrument.

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Appendix A: Responses to Survey Validation Questions

Table A1. What is your gender?		
Answer	Count	Percentage
Female	21	19%
Male	87	81%
Note. Item level response rate: 97% (108 of 111)		

Table A2. What is your primary disciplinary background?		
Answer	Count	Percentage
Engineering	103	93%
Other STEM	1	<1%
Business	2	2%
Humanities	2	2%
Other	3	3%
Other Responses: Engineering AND Business; CS; Digital Media		
Note. Item level response rate: 100% (111 of 111)		

Table A3. Please indicate your engineering sub-discipline(s) from the list below (check all that apply).		
Engineering Sub-discipline	Count	Percentage
Mechanical Engineering	51	50%
Biomedical Engineering	21	20%
Electrical Engineering	16	16%
Electrical/Computer Engineering	14	14%
Industrial/Manufacturing/Systems Engineering	11	11%
Engineering (General)	9	9%
Civil Engineering	8	8%
Computer Engineering	7	7%
Engineering Management	7	7%
Aerospace Engineering	6	6%
Chemical Engineering	6	6%
Computer Science (outside engineering)	6	6%
Metallurgical & Matris. Engineering	4	4%
Other	4	4%
Biological Engineering & Agricultural Engineering	3	3%
Civil/Environmental Engineering	3	3%
Environmental Engineering	2	2%
Nuclear Engineering	1	<1%
Note. Item level response rate: 92% (102 of 111)		

Appendix B: Survey Instrument

2015 Current Capstone Practices and Entrepreneurship

Hello,

We are interested in learning about the extent to which engineering Capstone design courses provide students with opportunities to practice entrepreneurial competencies. Please use this questionnaire to reflect on your two most recent engineering Capstone design courses and tell us about your current practices in this area.

We value your responses and ask that you complete the survey to the best of your ability even if some questions do not appear relevant to your discipline. All answers will contribute to the understanding of current capstone practices.

The survey is 21 questions and should only take 5 to 10 minutes to complete. If you have any questions, please contact Ari Turrentine, Research and Evaluation Analyst at VentureWell (aturrentine@venturewell.org).

Sincerely,

The VentureWell Team

Teaching Capstone

DO YOU TEACH CAPSTONE DESIGN TO UNDERGRADUATE ENGINEERING STUDENTS? *

Please choose **only one** of the following:

- Yes
- No

Capstone Practices

WHAT GROUP MOST FREQUENTLY INITIATES CAPSTONE DESIGN PROJECT IDEAS? PLEASE RANK THE FOLLOWING LIST FROM MOST FREQUENTLY (1ST) TO LEAST FREQUENTLY (3RD).

Please number each box in order of preference from 1 to 3

- Instructors
- Sponsors
- Students

WHAT GROUP MOST FREQUENTLY DEFINES THE PROBLEM SCOPE OF CAPSTONE DESIGN PROJECTS? PLEASE RANK THE FOLLOWING LIST FROM MOST FREQUENTLY (1ST) TO LEAST FREQUENTLY (3RD).

Please number each box in order of preference from 1 to 3

- Instructors
- Sponsors
- Students

HOW MANY CAPSTONE DESIGN PROJECTS ARE FUNDED BY A SPECIFIC INDUSTRY SPONSOR?

Please choose **only one** of the following:

- None
- A few
- Half
- Most
- All

HOW OFTEN DO INDUSTRY SPONSORS PROVIDE UNRESTRICTED GIFTS TO SUPPORT THE ENTIRE COURSE, RATHER THAN A SPECIFIC STUDENT PROJECT?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always

TO WHAT EXTENT IS THE SUCCESS OF THE FINAL PROJECT/PRODUCT EVALUATED BY THE FOLLOWING:

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Always
Meeting technical requirements	○	○	○	○	○
Meeting end user and/or customer needs	○	○	○	○	○
Meeting sponsor needs	○	○	○	○	○

HOW OFTEN ARE THE FOLLOWING REQUIRED IN THE COURSE?

Please choose the appropriate response for each item:

	Never	Rarely	Sometimes	Often	Always
Working prototype	○	○	○	○	○
Customer-validation of solution	○	○	○	○	○
Assessment of market size	○	○	○	○	○
Business model or commercialization plan	○	○	○	○	○

HOW OFTEN IS "FAILING FORWARD" (USING FAILURE TO ITERATE THE DESIGN) ENCOURAGED?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always

HOW OFTEN DO PROJECTS CONTINUE WHEN THE COURSE IS COMPLETE?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always
- I don't know

HOW OFTEN DO STUDENTS PURSUE PRIOR WORK (E.G., WORK THAT WAS UNDERTAKEN IN A PRIOR SEMESTER EITHER AS A HOBBY PROJECT OR PART OF A COURSE REQUIREMENT)?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always

Your Institution

DOES YOUR INSTITUTION HAVE INFRASTRUCTURE TO SUPPORT STUDENTS WHO DEVELOP THEIR PROJECTS BEYOND THE COURSE?

Please choose **only one** of the following:

- No
- Uncertain
- Yes

CAN STUDENTS OWN INTELLECTUAL PROPERTY THAT THEY CREATE DURING THE CAPSTONE DESIGN COURSE?

Please choose **only one** of the following:

- No
- Uncertain
- Yes

FOR SPONSORED PROJECTS, HOW OFTEN ARE STUDENTS REQUIRED TO SIGN AN EXCLUSIVE LICENSE AGREEMENT WITH THE SPONSOR?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always

HOW OFTEN IS IP PROTECTION PART OF THE COURSE CURRICULUM?

Please choose **only one** of the following:

- Never
- Rarely
- Sometimes
- Often
- Always

PLEASE RATE THE IMPORTANCE OF THE FOLLOWING EDUCATIONAL OUTCOMES FOR YOUR CAPSTONE DESIGN COURSE

Please choose the appropriate response for each item:

	Unimportant	Of Little Importance	Moderately Important	Important	Very Important
Technical competence	○	○	○	○	○
Competence in team work	○	○	○	○	○
Ability to recognize market opportunities	○	○	○	○	○
Understanding pathways to technology commercialization (e.g., licensing, venture creation)	○	○	○	○	○

IN YOUR OPINION, HOW IMPORTANT IS IT TO INCREASE THE DEGREE TO WHICH THE FOLLOWING ARE SUPPORTED (A) IN YOUR CAPSTONE DESIGN CLASS AND (B) BROADLY ON YOUR CAMPUS

Please choose the appropriate response for each item:

(a) in your capstone design class

	Unimportant	Of Little Importance	Moderately Important	Important	Very Important
Student sponsored projects	○	○	○	○	○
Customer validation	○	○	○	○	○
Assessment of market size	○	○	○	○	○
Business model or commercialization plan	○	○	○	○	○
Understanding of intellectual property	○	○	○	○	○
Infrastructure to help students continue to develop their project once the course ends	○	○	○	○	○

(b) broadly on your campus

	Unimportant	Of Little Importance	Moderately Important	Important	Very Important
Student sponsored projects	○	○	○	○	○
Customer validation	○	○	○	○	○
Assessment of market size	○	○	○	○	○
Business model or commercialization plan	○	○	○	○	○
Understanding of intellectual property	○	○	○	○	○
Infrastructure to help students continue to develop their project once the course ends	○	○	○	○	○

About You

WHAT IS YOUR GENDER?

Please choose **only one** of the following:

- Female
- Male
- Other

WHAT IS YOUR PRIMARY DISCIPLINARY BACKGROUND? *

Please choose **only one** of the following:

- Engineering
- Other STEM
- Business
- Social Science
- Humanities
- Other

PLEASE INDICATE YOUR ENGINEERING SUB-DISCIPLINE(S) FROM THE LIST BELOW (CHECK ALL THAT APPLY).

Please choose **all** that apply:

- Aerospace Engineering
- Architectural Engineering
- Biological Engineering and Agricultural Engineering
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Civil/Environmental Engineering
- Computer Engineering
- Electrical Engineering
- Electrical/Computer Engineering
- Engineering (General)
- Engineering Management
- Engineering Science and Engineering Physics
- Environmental Engineering
- Industrial/Manufacturing/Systems Engineering
- Mechanical Engineering
- Metallurgical and Matris. Engineering
- Mining Engineering
- Nuclear Engineering
- Petroleum Engineering
- Computer Science (outside engineering)
- Other:

WHAT TYPES OF STUDENTS ARE ENROLLED IN YOUR CAPSTONE DESIGN COURSE? (INDICATE APPROXIMATE % OF EACH)

Please write your answer(s) here:

- Engineering
- Other STEM discipline
- Social Sciences
- Humanities
- Other

USE THIS SPACE TO SHARE ANY OTHER THOUGHTS ABOUT INTEGRATING ENTREPRENEURSHIP INTO ENGINEERING CAPSTONE DESIGN COURSES.

Please write your answer here:

Thank you for completing this survey.