Teaching Entrepreneurial Thinking Through a Companion Course for All Types of Capstone Senior Design Projects

Mrs. Sandra Furnbach Clavijo P.E., Stevens Institute of Technology

Sandra Clavijo is the manager for the Innovation, Design and Entrepreneurship at Stevens (IDEAS) program in the School of Engineering & Sciences which coordinates the design and innovation spine, PROOF Lab and the Senior Design Expo. Sandra also teaches Senior Innovation and Introduction to Entrepreneurship Thinking. Before coming to Stevens, Sandra worked as a consulting engineer with Stantec and T&M Associates specializing in Urban Land Redevelopment and Municipal Engineering. Sandra holds a B.S. Degree in Civil & Environmental Engineering, an A. B. degree in Art History, and a Master of Engineering degree in Engineering Management from Stevens Institute of Technology. She also holds a Professional Engineering license in NJ.

Dr. Leslie R. Brunell, Stevens Institute of Technology

Leslie Brunell, PhD, PE is a Teaching Professor at Stevens Institute of Technology. She coordinates both the civil and multidisciplinary engineering senior design projects. These projects are the culmination of the undergraduate engineering experience. Students design an innovative solution to a complex problem. She has recruited professional sponsors who mentor the civil engineering design projects. The projects expose the civil engineering students to real world design problems. The students gain first hand experience communicating professionally, developing schedules, meeting deadlines and preparing professional quality reports and presentations. Prof. Brunell is the director of the Water Resouces graduate program. She also teaches Fluid Mechanics, Surveying and Water Resources.

Dr. Keith G. Sheppard, Stevens Institute of Technology

Dr. Keith G. Sheppard is Senior Advisor to the Dean in the Charles V. Schaefer, Jr. School of Engineering and Science and a professor in the Department of Chemical Engineering and Materials Science. His research interests have included electrochemical aspects of materials synthesis and environmental degradation of materials. His education in the U.K. included B.Sc. (University of Leeds) and Ph.D. (University of Birmingham) degrees in Metallurgy and a diploma in Industrial Administration (Aston University). He was the recipient of the Henry Morton Distinguished Teaching Professor Award in 2009. As Associate Dean, Prof. Sheppard had a leading role in the development of the undergraduate engineering curriculum at Stevens, including innovations in design education and initiatives to include entrepreneurship, sustainability, and global competency for undergraduate students.

Prof. Kishore V. Pochiraju, Stevens Institute of Technology

Kishore Pochiraju is the Associate Dean for Undergraduate Education and a Professor in the Mechanical Engineering department at Stevens Institute of Technology. He recently served as the Founding Director of the Innovation, Design and Entrepreneurship Program at Stevens (IDEaS) and prior to that, as the Director of the Design and Manufacturing Institute, a research center at Stevens. Prof. Pochiraju received his Ph.D. in 1993 from Drexel University and joined Stevens after working as a postdoctoral fellow at the University of Delaware. His expertise spans product design, advanced manufacturing, materials insertion, and knowledge-based systems integration. His current externally-funded research is on the design of real-time lightweight robotic systems, high-temperature materials, and micro-/nano-scale devices. He is a member of ASME, ASEE and the American Society for Composites (ASC).

Teaching Entrepreneurial Thinking through a Companion Course for all types of Capstone Senior Design Projects

Abstract

Entrepreneurial thinking is recognized as important to the engineering curriculum; however, the typical entrepreneurship course is not applicable to all senior design projects, especially those from civil engineering. We recognized that product-based entrepreneurship courses need to be expanded and more flexible. Therefore, we have developed and implemented Senior Innovation, a companion course to senior design that focuses on entrepreneurial thinking in engineering design. Our main focus is to ensure students can communicate the value of their design - be it a product, service design, process design, or competition entrant - and develop and deliver an elevator pitch in our university-wide pitch competition.

Before we implemented Senior Innovation, certain disciplines, such as civil engineering, were left out of competing in our pitch competition, because they did not produce a physical product. Based on recent assessment data, we can conclude that 85 percent of engineering students, and 88 percent of civil engineering students, believe they can identify and communicate value through an elevator pitch after having taken Senior Innovation. This confirms that our course is valuable to all engineering disciplines and can be applied to all service design, process design, and competition entrants, as well as product-based senior design projects. This paper focuses on the creation of the companion course, Senior Innovation, and the learning objectives and methods used to teach entrepreneurial thinking, as well as assessment data and examples of how the course applies to non–product-based senior design projects.

Introduction

Entrepreneurial thinking is recognized as important to engineering curricula and is currently a major initiative at most universities and the Kern Entrepreneurship Education Network (KEEN) [1], [2], [3]. Entrepreneurial thinking is a combination of entrepreneurial mindset and innovation, which KEEN defines as: being able to design value-added products and processes that create demand through innovation, resulting in positive cash flow, revenue, and regenerative profits for the enterprise producing the product. This is different from entrepreneurship, which is self-employment through business ownership [3].

At Stevens Institute of Technology (Stevens), we recognized that the two-semester capstone design project was the perfect opportunity to explore hands-on education in innovation and entrepreneurial thinking by creating a companion course, delivered concurrently with senior design and focused around the same senior design project. Our entrepreneurial thinking course is called Senior Innovation I (2 credits) and Senior Innovation II (1 credit), taught concurrently with senior design courses, Capstone Design I (3 credits) and Capstone Design II (3 credits). Students work on the same teams and same project in both the design and innovation classes throughout the senior year.

Most courses on entrepreneurship tend to be centered around product-based designs, are limited to business creation, and are taught by professors from outside the engineering school—for instance in a business school—and reach a limited portion of the student body [3], [4]. While some engineering senior design projects result in a product or prototype, many senior design projects do not. Projects can also focus on service design, process design, and design competitions [5]. We recognized that, for students to learn and apply entrepreneurial thinking in their senior design project, we need a required flexible course that can embed elements of entrepreneurial thinking in the context of all types of design projects.

Our main focus is to ensure that the students can communicate the value of their solution, whether a product, service, process, or competition entrant, and compete in our university-wide pitch competition. Industry-sponsored projects present other challenges but provide unique opportunities to establish how entrepreneurial thinking can be effective in succeeding while employed in corporate settings [6], [7], [8]. Many students relate entrepreneurism with starting a business or perhaps working at a startup company with some participation in equity, but rarely do they appreciate the value of entrepreneurial skills within the competitive corporate environment.

This paper will focus on how we developed and delivered our year-long companion course, Senior Innovation, and how the following learning outcomes were achieved through delivery of this course: define business value propositions of the design project; estimate and identify prospective revenue streams; analyze market viability for a given product/service; develop basic components of a business plan; create an effective executive summary; and develop and deliver an effective pitch. From our 2016-2017 survey results of Senior Innovation, we can conclude that civil engineering students master the same learning outcomes as all engineering students, and therefore the type of senior design project does not matter: all students can learn entrepreneurial thinking through their senior design project.

Motivation: Required courses are not optional

Stevens takes pride in a broad-based engineering curriculum with substantial numbers of credits required in math, science, humanities, and management. Entrepreneurial thinking and entrepreneurial mindset are sought after as additional skills for engineering students, from the perspective of employers but also as skills necessary to make lasting contributions to society [9], [10], [11]. More than half of all engineering programs provide entrepreneurship learning options for students, including minors, certificates, and concentrations [12]. At Stevens, the business school offers a minor to engineering students, but the program traditionally has a low enrollment.

Table 1. Percentage of Engineers Taking Entrepreneurship Minor at Stevens

	Engineering students enrolled for entrepreneurship minor	Total engineering students	Percentage
2017-2018	2	1946	0.10%
2016-2017	2	1894	0.11%

2015-2016	2	1888	0.11%
2014-2015	2	1788	0.11%
2013-2014	6	1736	0.35%
2012-2013	6	1693	0.53%

Table 1 shows that about a tenth of a percent of students can be expected to enroll for an entrepreneurship minor. This situation may not be unique to Stevens, as a major study by Cao et al. [4] found that just 18 students out of the 7197 that were surveyed had a minor in entrepreneurship (0.25 percent). Studies by Duval-Couetil et al. [11] have shown that interest in entrepreneurship strengthens when students take one or more courses in entrepreneurship. To build entrepreneurial thinking into our curriculum, we concluded that a required course that builds and integrates elements of entrepreneurial thinking into our existing curriculum was necessary.

Integrating senior design and entrepreneurial experiences

Examining the structure of our engineering curriculum, we identified that we can seamlessly introduce courses related to entrepreneurial thinking in the freshman and senior years. While our freshman course on entrepreneurial thinking is taught under the leadership of the business school and independent of the technical curriculum, the senior entrepreneurship course tightly integrates with the two-semester senior design curriculum. At this time, we have no entrepreneurial thinking courses during the sophomore and junior years; however, curriculum changes in our design courses are moving toward reinforcing entrepreneurial thinking.

Senior design projects come in various types, and various benefits are associated with each [5]. It was challenging to design a companion entrepreneurial thinking course that could be applied across all eight of our current engineering programs: Biomedical, Chemical, Civil, Computer, Electrical, Environmental, Mechanical, and Naval Engineering, as well as the Engineering Management program. Only about half of our projects fall into the category of product design with a prototype. The product projects, whether hardware, software, or a combination, work well as examples in traditional entrepreneurship or business planning classes. Many of our biomedical engineering students develop medical devices, and mechanical engineering students develop robots and gadgets, all of which are ideal examples for identifying customers, value propositions, and fundraising strategies. Table 2 shows the distribution of project types in 2016 and 2017.

Table 2. Types of Senior Design Projects at Stevens

Types of Engineering Senior Design Projects				
	2017	% of total	2016	% of total
Product/Prototype	50	49.5%	47	46.1%
Service	10	9.9%	15	14.7%
Process	11	10.9%	11	10.8%
Competition	10	9.9%	8	7.8%
Industry Affiliated/Sponsored	20	19.8%	21	20.6%

Total Projects	101		102	

To determine and assess some effective ways of teaching entrepreneurial thinking in the context of non–product-oriented projects, we focused on the civil engineering students, who mainly work with professional engineering mentors from local consulting companies and provide services to ongoing projects. For example, they might perform structural calculations for the design of a high-rise building in Manhattan, or develop a site plan for a new school that includes storm water, traffic, and construction-staging plans. It can be difficult for these students to follow the same path to market and develop estimates of costs of service and profit margins. Concepts like costs of goods sold, margins, and new product features, when discussed in entrepreneurship courses, rarely resonate with these students.

Table 3. Types of Civil Engineering Senior Design Projects at Stevens

Types of Civil Engineering Senior Design Projects				
	2017	**% of total**	**2016**	% of total
Faculty Product/Prototype	1	8.3%	1	7%
Service	1	8.3%	3	21%
Process	0		0	
Competition	1	8.3%	1	7%
Industry Affiliated/Sponsored	9	75.0%	9	64%
Total Projects	12		14	

We find similar issues with our chemical engineering students who design and model a new chemical process, for example, using waste materials for biodiesel, or reusing spent uranium for a secondary use. Other teams compete in competitions such as the EPA's national Campus RainWorks Challenge competition, which challenges students to create a master plan or site design to manage runoff from their college campus. Or NASA, which challenges students to think about new types of space station designs. Many mechanical engineering students work each year on the Formula One or Baja SAE student design competition for developing racing cars with specific criteria.

Industry-sponsored projects have a specific problem focus and expect innovative and out-of-the-box thinking from engineering students. In one project last year, the students designed an industrial automation system that reduced non–value-added labor by introducing a process combination. Students conceived the innovation by working on the company's production line for a single day as a production worker. The project mentors from the company were able to secure substantial investment from their management for the automation project based on the project prototype. Such experiences easily translate as examples of the value of entrepreneurial thinking in corporate environments.

Senior design course projects do not fit in one-size-fits-all examples in entrepreneurship courses. To give these students the opportunity to practice customer discovery, value creation, lean business model canvas, and pitching in competition, we needed an innovative course that was more flexible, with instructors who are skilled in service based-business models and consulting models to guide the students. Moreover, we decided to refrain from using iconic examples (e.g, Bill Gates and Steve Jobs) in favor of examples from our own design and innovation ecosystem (alumni and local entrepreneurs).

Extracurricular experiences

All engineering students must work on a year-long capstone design project, and many schools have tried to exploit this opportunity to work on a project that has commercial value [13]. Many schools will encourage students to compete in VentureWell e-teams or BMEidea, local or regional startup competitions, and other "beyond-the-classroom" initiatives [14]. While these opportunities reinforce entrepreneurial thinking for motivated students working on prototype/products type of projects, 50 percent of our senior design projects are not eligible to compete in these opportunities due to the pedagogical nature of their senior design project [5].

Several studies have been done about types of entrepreneurial offerings at various universities [4], [12]. More than half of the ASEE listed engineering programs provided entrepreneurship options, with approximately a quarter having more substantive programs, such as minors, centers, and other structured programs that are based in the engineering school. These courses can be hosted in a completely different school of the university and are often not linked with the engineering school or curriculum [4]. We have found that Stevens engineering students who already have a heavy load of courses do not or cannot take these courses.

Integrating innovation and entrepreneurship curriculum with design

To obtain buy-in from the students and our engineering faculty that entrepreneurial mindset and innovation skills are relevant and applicable to all projects, we had to develop a more inclusive model with a broader use of entrepreneurial thinking. We mapped terminology equivalencies across domains, made requirements consistent for all majors, collaborated with our business and engineering colleagues, and synchronized milestones. This enabled us to send a unified message that all senior design projects require entrepreneurial thinking, and that all students should be prepared to compete in the pitch competition - no exceptions.

The first step was to devise a model that maps product-to-service equivalencies. For example, cost of goods sold becomes cost of services rendered, and the same fundamental accounting applies for either: charge more than it costs and achieve a true profit margin. Customers can be referred to as *clients,* and instead of thinking about offering products, these projects can be thought of as providing services. For example, students in civil engineering would calculate how much to charge to prepare structural calculations and design drawings for a high-rise building. They would then look at the average starting salaries of engineers, fringe benefits, and overhead costs, such as office space and software licensing, to understand the total cost for this service job and come up with a cost estimate to bill these clients. For the product/service equivalency for a target market and a marketing plan, students are taught to treat each client as their first client.

They are challenged to identify more clients with similar needs, or with similar problems, and this is how scalability is taught and applied. Just as the product counterparts offer features, we encourage these students to think of a portfolio of service offerings.

Another main focus is to treat all projects the same and have consistent requirements across all class sections; no project is exempt from the entrepreneurial thinking course, nor the pitch competition, and all projects need to define their value and impact. Many studies say this is the most important component of an entrepreneurship education [15], [16], [17], [18]. Students often struggle with understanding and communicating value and can be particularly difficult for non-product senior design projects that are unable to use a return on investment model. While toll bridges might eventually have an actual return on investment, we encourage students to look beyond return on investment to define their own metrics to convey the impact of their project.

We use example projects in class, such as the Pulaski Skyway rehabilitation project and the Washington Street Project in Hoboken, New Jersey, to help students understand that value is not always the cheapest design [19]. The Pulaski Skyway is a key artery to New York City. Several options to rehabilitate the deck were proposed, but ultimately the time of the construction was lengthened to maintain traffic flow out of New York City. The Washington Street Project encompasses a complete rehabilitation of the main street of Hoboken, from infrastructure upgrades to improved traffic timings and an increased focus on pedestrian safety. The website for this project says, "Washington Street is Open for Business." This type of example can provide students an illustration of what is valuable to the client. The City of Hoboken, during construction, is focusing on keeping businesses open and water turned on for the establishments on the main street [20]. For many of these local projects, we are able to have key members of the design team, mostly Stevens alumni, speak with the students. Other metrics useful for value and impact are gallons of flood water contained, rentable/usable space increased, man-hours reduced, insurance claims reduced, and so forth, and these can all be converted to actual dollar amounts.

An example project from 2016 focused on gallons of water as a metric to communicate value to their clients. The team was working with the County Task Force in Rockland County, New York, to develop Green Infrastructure designs throughout the county to reduce surface runoff and increase infiltration. To convey the advantage of their designs to the stakeholders, the students equated the gallons of water conserved to equivalent gallons used for washing and toilet-flushing, something everyone could understand that has a dollar amount equivalent.

All students must practice and prepare for the pitch competition in the entrepreneurial thinking course and are graded on their performance in class. Our competition is an elevator-style competition that adheres to a three-minute limit, with no visuals, which encourages the students to focus on value, instead of technical capabilities. Each team member must deliver the pitch in the class, and the best presenter among each team is chosen to represent that team in the quarterfinal competition. If a student reads the pitch instead of having it prepared and memorized, he or she cannot get higher than a C on the solo grade. This ensures all team members get the benefit of learning to pitch [21].

Quarterfinal competitions are held in class sections, but the winners for the semifinal and final rounds of the competition are decided by external independent judges who have experience in entrepreneurship, intrapreneurship, and engineering. We host our final competition on the same day as the annual Stevens Innovation Expo, our senior design project showcase. Competition prizes are donated from alumni and corporations: $10,000 for first prize, $5,000 for second prize, and $2,500 for third prize. We have steadily increased the prize money, and the excitement has grown on campus, encouraging students to be enthusiastic about the competition.

Experienced industry adjunct instructors that have started businesses and worked in consulting or a service-based industry teach the entrepreneurial thinking courses. These instructors serve as business mentors for the projects for the year-long commitment and do not guide students on achieving technical success. Instructor training and cohesion is an important part of this new model. The scale of this course demands eight instructors to work together to keep the course consistent, under the leadership of a course coordinator, with the additional layer of keeping it concurrent with the senior design courses. Each semester, we hold a four-hour training seminar with all instructors and also have monthly meetings or conference calls. We pair the industry experience of the instructors with students in a similar discipline so real-life examples can be brought into the classroom. Most of these instructors work with their technical counterpart(s) to ensure the classes are in unison, and that any concerns can be quickly addressed.

To implement this course, we worked with the individual senior design course coordinators for each program and have created and implemented a synchronized timeline and milestones plan that is used across all majors – see Table 4. We have designated sections of our innovation courses that the students can conveniently fit into their schedules. This current design and innovation pedagogy has now been implemented across all engineering programs in the School of Engineering & Science and is comprised of biomedical, mechanical, civil, environmental, naval, chemical, electrical, and computer engineering, as well as the engineering management program. Each year, around 425 senior students work on 102 different projects, divided into approximately 14 Senior Innovation sections.

Table 4. Timeline and Milestone Synchronization in Capstone Design and Senior Innovation Courses

Timeline	Capstone Design I & II	Senior Innovation I & II
Phase I (Define)	Design Requirements	Mission Statement/Teaming
	Applicable Codes, Standards, Regulations	Stakeholders and Needs
		Needs Analysis
Early October	**Milestone #1: Customers, Needs, Requirements, Needs-Requirements Mapping**	
Phase II (Innovate)	Concept Generation	Project Schedule
	Design Evaluation Frameworks: Modeling, Testing, Prototyping	Competitive Intelligence
Mid November	**Milestone #2: Project Plan, Concepts, Concept Selection, Analysis and Testing Plan**	
Phase III (Design)	Design – Analysis – Redesign Loop using Simulations and Prototypes	Business Opportunity Development
		Intellectual Property Selection
Late January	**Milestone #3: Design Performance and Cost Review with Alpha^{+} Prototype Demonstration**	
Phase IV (Optimize & Demo)	Design Optimization and Prototype Refinement	Lean Canvas Business Plan
		Pitch Presentation Preparations
Last Wednesday of March	**Milestone #4: Beta Demonstration^{++} of Optimized Design**	
Phase V (Document)	Design Documentation, Design Rationale, BOM and all Specifications	Invention Disclosures and Innovation Expo Preparation
May – Final Week	**Milestone #5: Final Report Submission, Innovation Expo.**	
	$^{+}$Alpha demonstration: Show all the components and sub-systems and how they fit together. System integration is not necessary but functionality of all individual sub-systems must be demonstrated. $^{++}$Beta Demonstration: All sub-systems must be integrated and the system must be fully functional. The team must be able to demonstrate the operations of the design in realistic user environments.	

The course is set up as a workshop-style course. Topics are introduced and then discussed with the teams to see how each topic is applicable to the individual projects. Students are able to apply the topic to their own projects, as well as other teams' projects in an open setting. Topics covered in the two courses are listed below in Table 5.

Table 5. Syllabus Material for Senior Innovation I and Senior Innovation II

Fall Semester (2 credits - 1x per week 1:50 min)	
Topics	**Activities**
Team Building	Team Outing
Discussions on Meeting Management	Meeting Minutes
Customer Needs Analysis	Customer Voice Table
Stakeholder Perceptions	Stakeholder Table
Voice of Customer Analysis	
Project Charter & Mission	Mission Statement
Project Scope Statement	Scope Statement
Project Milestones	Project Schedule
Assumptions & Constraints	
Presentation Basics	Presentation Deck Review
Risk & Change	
Intellectual Property	Patent Review (if applicable)
Project Charter Review	Project Charter Draft
Invention Versus Innovation	
Value Proposition	Lean Canvas Draft
Market Segmentation	
Customer Profile Analysis	
Spring Semester (1 credit - 1x per week 50 min)	
Topics	**Activities**
Business Value Proposition	Project Abstract
Lean Canvas Business Plan	Executive Summary
Communication of Business Opportunities	Pitch Outline
Individual Pitch Presentations	3-Min Individual Pitch
In-Class Quarterfinal Pitch Competition	Team Pitch Participation
Business Plan Development	Lean Business Canvas

Results: Case studies

The implementation of the Senior Innovation companion course to the senior capstone design project has provided the opportunity for all our engineering seniors to incorporate an entrepreneurial mindset while completing their senior design projects. Students have gained an understanding of the business value of their proposed designs, with each team required to develop a business plan and identify possible revenue streams for their project. The pitch competition at the conclusion of the academic year allows the students to showcase their entrepreneurial spirit. The success of the service design, process design, and competition entrants illustrates that the entrepreneurial mindset can be applied to non–product-based senior design projects.

An example project from 2016 included students who entered an Environmental Protection Agency (EPA) competition focused on reducing the amount of stormwater on college campuses. Initially, these students did not think they could compete or win in the school-wide pitch competition, because their project was narrowly focused on creating a stormwater management plan for Stevens campus. After working in our innovation course, they were able to define the value of their design process and finished in second place out of 125 projects in the pitch competition. In addition to making the campus greener by reducing the amount of pollutants going into our local bodies of water, they also found the cost savings of the reduced amount of discharged water and the potential savings of reused water for landscaping maintenance. They attributed their success to the interviews they had conducted with the Stevens facilities department. After the feedback from our facilities personnel, they proceeded to interview local government officials in the City of Hoboken and realized design services in stormwater management were very valuable, and that the team could sell consulting services to cities and campuses in flood-prone areas.

Another example from the Chemical Engineering department in 2016 involved students that designed a more sustainable, efficient, safe, and novel method of extracting uranium from spent nuclear fuel through crystallization. These students were very disappointed that their project wouldn't end up with a cool prototype to pitch at the competition. They found renewed interest in their project when they visited the Indian Point Energy Center and arranged to speak with various staff at the facility, and then used this customer as a base-case for design. They researched waste disposal facilities, such as Barnwell, Compact Waste Facility, Energy Solutions, and Hanford, which is the alternative for getting rid of spent nuclear fuel. They found that locally, nuclear energy facilities in New York and New Jersey store 3,950 metric tons and 2,940 metric tons of nuclear fuel, respectively, and have contributed $1.02 billion and $782.5 million, respectively, to the Nuclear Waste Fund. Across the country, almost 75,000 metric tons of uranium has been generated with more than $21 billion contributed to the Nuclear Waste Fund. The student team's unique approach to reprocessing spent nuclear fuel earned them a first-place finish in our pitch competition.

Discussion

We have included two tables of survey assessment data. Table 6 includes the assessment data from the entire engineering population, and Table 7 is the segregated assessment data from the two civil engineering sections. The data were taken at the end of the senior design project and pitch competition after the year-long Senior Innovation course and Capstone Design course. Response rates were similar, but civil engineering had a slightly higher response rate at 68 percent, while the total survey was 55 percent.

The main summary of these tables shows that our companion entrepreneurial thinking course is effective across engineering students, and that civil engineering students working on non-product-based senior design projects are also learning and applying entrepreneurial thinking.

Table 6. Survey Results - Spring 2017 Senior Innovation Learning Outcomes - All Sections

Spring		2017				
Population		463				
Response Rate		55%				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Agree & Strongly Agree
L1 I am able to define the business value proposition of my design project	2%	4%	9%	37%	48%	85%
L2 I am able to estimate and identify prospective revenue streams	2%	9%	12%	34%	51%	85%
L3 I am able to analyze market viability for a given product/service	3%	6%	12%	36%	43%	79%
L4 I am able to develop basic components of a business plan	3%	1%	11%	36%	49%	85%
L5 I am able to create an effective executive summary	2%	4%	10%	37%	47%	84%
L6 I am able to develop and deliver an effective pitch	2%	2%	12%	33%	51%	84%

Table 7. Survey Results - Spring 2017 Senior Innovation Learning Outcomes - Civil Engineering

Spring		2017				
Population—Civil Engineering Sections		74				
Response Rate		68%				
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Agree & Strongly Agree
L1 I am able to define the business value proposition of my design project	2%	4%	6%	36%	52%	88%

L2 I am able to estimate and identify prospective revenue streams	4%	10%	4%	34%	48%	82%
L3 I am able to analyze market viability for a given product/service	2%	6%	6%	34%	52%	86%
L4 I am able to develop basic components of a business plan	2%	0%	8%	34%	56%	90%
L5 I am able to create an effective executive summary	2%	0%	10%	34%	54%	88%
L6 I am able to develop and deliver an effective pitch	2%	4%	6%	38%	50%	88%

Concluding remarks

We are anticipating our engineers are now graduating with some entrepreneurial thinking skills and are ready to compete in the new global economy [6]. By designing and implementing a companion entrepreneurial thinking course for the two-semester capstone design, all engineering students are provided the opportunity to apply entrepreneurial thinking on a technical design project and a vast majority of them—85 percent—have indicated they can now identify the value proposition of an engineering project. We designed a course that was flexible enough to include the various categories of senior design projects, like product design, service design, process design, sponsored projects, and design competitions, as well as hire adjunct faculty that have experience in these diverse areas. Although Stevens has room for improvement, especially in the sophomore and junior years, we have a platform and process in place to deliver a course that focuses on customer requirements, value recognition, and value communication, and our graduates have learned the art of pitching an idea.

Limitations

We try to keep similar projects together in Senior Innovation courses and match instructors' backgrounds to the types of projects. However, with scheduling of other courses and other logistical constraints, this is not 100 percent perfected. Senior design course structure can vary from having one advisor for all projects in a smaller department, to a larger department engaging all of its faculty in advising design projects (typically one to three projects per faculty member). It can be a challenge for our adjunct instructors to work with the specific senior design faculty advisors.

Sometimes the customer discovery process directs students to change their project completely, and with the timeline and other considerations in place, students are unable to make these changes in their actual design. Also, if the students discover there is no market, or little market, for their potential project in the spring of their senior year, they can become disengaged with their project and end the year on a sour note.

Lastly, our pitch competition does not help with starting businesses. Our students typically have jobs lined up and do not want to turn them down to work on a potential business idea. Therefore, winning teams will most likely not start a business based on their senior design project.

Additionally, we are contemplating a process to continue projects from year to year by exposing junior class students to senior design projects early on during the year, as opposed to waiting until the end-of-the-year Innovation Expo.

Additional improvements could be surveying students in the beginning of their senior year, and then at the end of the senior year, to ensure this course can be attributed to teaching the desired entrepreneurial thinking.

References

[1] S. Nichols and N. E. Armstrong, "Engineering entrepreneurship: Does entrepreneurship have a role in engineering education?" *IEEE Antennas and Propagation Magazine*, vol. 45(1), pp. 134-138, 2003.

[2] T. Byers, T. Seelig, S. Sheppard, and P. Weilerstein, "Entrepreneurship: its role in engineering education," *The Bridge*, vol. 43(2), pp. 35-4, 2013.

[3] T. J. Kriewall and K. Mekemson, "Instilling the entrepreneurial mindset into engineering undergraduates," *The Journal of Engineering Entrepreneurship*, vol. 1(1), pp. 5-19, July 2010. [Online]. Available: http://www.jeenonline.com/Vol1/Num1/Vol1No1P1.pdf [Accessed March 1, 2018].

[4] E. Cao, S. Gilmartin, Q. Jin, C. Dungs, and S. Sheppard, "Business program participation and engineering innovation: an exploration of engineering students' minors, certificates, and concentrations," *The Journal of Engineering Entrepreneurship*, vol. 8(1), Winter 2017. [Online]. Available: http://jeenonline.com/Vol8/Num1/Paper_3_web.pdf. [Accessed Jan. 8, 2018].

[5] P. Brackin, D. Knudson, B. Nassersharif, and D. O'Bannon, "Pedagogical implications of project selection in capstone design courses," *International Journal of Engineering Education*, vol. 27(6), p. 1164, 2011.

[6] D. F. Kuratko, J. S. Hornsby, D. W. Naffziger, and R. V. Montagno, "Implementing entrepreneurial thinking in established organizations," *S.A.M. Advanced Management Journal,* vol. 58(1), p. 28, 1993. [Online]. Available: http://ezproxy.stevens.edu/login?url=https://search.proquest.com/docview/231226652?accountid=14052. [Accessed Jan. 30, 2018].

[7] E. Thornberry, "Corporate entrepreneurship: teaching managers to be entrepreneurs," *Journal of Management Development*, vol. 22(4), pp. 329-344, 2003.

[Online]. Available: https://doi.org/10.1108/02621710310467613. [Accessed March 1, 2018].

[8] R. H. Todd, C. D. Sorensen, and S. P. Magleby, "Designing a senior capstone course to satisfy industrial customers," *Journal of Engineering Education*, vol. 82(2), pp. 92-100, 1993.

[9] National Academy of Engineering, *The Engineering of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press, 2004.

[10] D. Carpenter and G. Feierfeil, "Cultivating an entrepreneurial mindset through interdisciplinary collaboration and networking," *Proceedings from the American Society for Engineering Education Conference, Honolulu, HI, USA, June 2007*. [Online]. Available: https://peer.asee.org/2419. [Accessed March 1, 2018].

[11] N. Duval-Couetil, T. Reed-Rhoads, and S. Haghighi, "Engineering students and entrepreneurship education: Involvement, attitudes and outcomes." *International Journal of Engineering Education*, vol. 28(2), p. 425, 2012.

[12] A. Shartrand, P. Weilerstein, M. Besterfield-Sacre, and K. Golding, "Technology entrepreneurship programs in U.S. engineering schools: An analysis of programs at the undergraduate level," *Proceedings from the American Society for Engineering Education Conference: 2010 Annual Conference & Exposition, Louisville, KY, USA, June 20-25, 2010*. [Online]. Available: https://peer.asee.org/16057. [Accessed Jan. 31, 2018].

[13] A. J. Conger, B. Gilchrist, J. P. Holloway, A. Huang-Saad, V. Sick, and T. H. Zurbuchen, "Experiential learning programs for the future of engineering education," *IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments, Dublin, Ireland, April 6-9, 2010*, pp. 1-14.

[14] S. Celis and A. Huang-Saad, "Students seeking different paths to entrepreneurial education," *Proceedings from the American Society for Engineering Education Conference, Seattle, WA, USA, June 14-17, 2015*.

[15] T. Standish-Kuon and M. P. Rice, "Introducing engineering and science students to entrepreneurship: models and influential factors at six American universities," *Journal of Engineering Education*, vol. 91(1), 2002.

[16] N. Bousaba and J. Conrad, "Promoting entrepreneurial skills through senior design projects," *Proceedings from the American Society for Engineering Education Conference, Seattle, WA, USA, June 14-17, 2015*.

[17] N. Fraser, M. Miles, M. Woods, and G. Lewis, "The creation of entrepreneurial engineers: a re-evaluation of the Standish-Kuon and Rice (2002) typology and the emergence of the entrepreneurial engineering education (EEE) typology," *The Journal of Engineering*

Entrepreneurship, vol. 8(1), Winter 2017. [Online]. Available: http://jeenonline.com/Vol8/Num1/Paper_6_web.pdf. [Accessed Nov. 17, 2017].

[18] C. Kitts, “Real world engineering enterprises: authentic development of an entrepreneurial mindset for engineering students,” *The Journal of Engineering Entrepreneurship*, vol. 7(3), Spring 2017. [Online]. Available: http://jeenonline.com/Vol7/Num3/Paper_03-web.pdf. [Accessed Jan. 8, 2018].

[19] C. Bastida, K. B. Winslow, D. Hartman, and S. Thorn, “Using big data for a transportation management plan: the General Pulaski Skyway bridge rehabilitation,” Transportation Research Board 94th Annual Meeting, Washington, DC, USA, Jan. 11-15, 2015.

[20] The Washington Street Rehabilitation & Design Project. [Online]. Available: http://www.washingtonstreetproject.com. [Accessed Jan. 22, 2018].

[21] N. Collamer, “The perfect elevator pitch to land a job,” Forbes.com, Feb. 4, 2013. [Online]. Available: https://www.forbes.com/sites/nextavenue/2013/02/04/the-perfect-elevator-pitch-to-land-a-job/#328ca9171b1d. [Accessed Jan. 22, 2018].