LAUNCHING AN INTERDISCIPLINARY ENTREPRENEURIAL CAPSTONE DESIGN EXPERIENCE

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Abstract

Cal Poly San Luis Obispo, a charter member of the VentureWell Pathways to Innovation Program, graduates approximately 1,000 undergraduate engineers each year, along with over 650 business students. Cal Poly engineers and business students contribute greatly to California's innovation economy. Based upon a deeply embedded "Learn by Doing" tradition, all students in all six colleges are required to complete a senior capstone project as part of their course of study, and this culminating experience is a large part of the educational culture of the campus. While the ingredients have been in place for Cal Poly to have an active innovation and entrepreneurship educational focus, there had previously been no curricular vehicle for students to explore interdisciplinary innovation and entrepreneurship activities as part of their senior capstone experience. This paper outlines the establishment of a cross-college entrepreneurial capstone course, the launch of the first cohort, and lessons learned to date in both starting and teaching such a course. The curriculum being used is outlined and specific changes that will be made in future years are also discussed. Lastly, the paper discusses expectation-setting based on the first cohort and establishes a baseline for further assessment.

Introduction

A senior capstone project experience is an integral part of the curriculum at Cal Poly that every senior must complete to graduate. Despite the university's deep senior capstone tradition and the large and growing involvement of students in the campus-wide five-year old Center for Innovation & Entrepreneurship (CIE), there was no vehicle for students to pursue entrepreneurship-oriented interdisciplinary senior projects. Before this course was launched, the engineering senior project opportunities consisted of the following (see Figure 1):

- Single discipline student-initiated projects (Smith 1958).
- Single discipline industry sponsored projects where project requirements are defined by the sponsor and where, in almost all cases, the work product is owned by the industry sponsor (Widmann and Mello 2007).
- Interdisciplinary (multiple majors from within the engineering college) industry sponsored projects. These are also projects where requirements are defined by an external sponsor and the work product is owned by the industry sponsor. This interdisciplinary track represented less than 4% of each graduating class of engineering students (Laiho, Savage, and Widmann 2010).

With no formal curricular path for students from different colleges to work together on student-derived innovations, isolated groups historically managed to partner on projects and get faculty approval and advising while working under the auspices of their home college's senior project

curriculum. These projects were rare, however, and without the students working within the framework of a common curriculum, the experiences were somewhat disjointed and team unity was difficult to accomplish.

	EXISTING INTERDISCIPLINARY ENGINEERING COURSE	EXISTING SINGLE DISCIPLINE COURSES	INTERDISCIPLINARY ENTREPRENEURIAL COURSE
Teaming Structure	Teams assigned by faculty	Teams assigned or individual projects	Team formation by students
Project Scope	Project scope defined	Project scope defined	Creativity and ideation define starting assumptions
Opportunity Identification	Receive requirements from industry sponsor	Requirements based on engineer's desires	Lean Startup methodologies
Customer Discovery	Industry sponsor calls/ meetings	Industry sponsor calls/meetings	Customer development as continuous process
Engineering Methodology	Design (fall), build (winter), test (spring)	Design (fall), build (winter), test (spring)	Agile engineering
Product Development	Design/build/test	Design/build/test	Iterative prototyping
Funding	Industry Sponsor	Internally supported	VentureWell Course Development Grant

Figure 1. Summary of the existing senior project options compared with the course described in this paper.

Given the established culture of senior projects, and growing interest in both interdisciplinary education and entrepreneurial programs, developing a course that tied these elements together was a logical curricular extension.

The Center for Innovation as a Pre-Curricular Testbed for Student Demand

The Cal Poly Center for Innovation & Entrepreneurship is unique in that it serves three connected constituencies: the campus; the San Luis Obispo community with downtown accelerator/incubator/co-working space; and the Small Business Development Center for Innovation. Because of this scope and top-level institutional support, cross-campus activity in entrepreneurship has grown very fast. CIE data showed a preponderance of involvement from engineering students (~60%), with business students next (~30%). While we had great success attracting students to our on-campus incubator, innovation competitions, hack-a-thons, etc., the most frequent request from students was for us to find ways to integrate these experiential, hands-on product/service/ business development activities into the formal curriculum. This course was designed to address that need by leveraging Cal Poly's senior capstone requirement and will serve as a perfect springboard for students who will be launching entrepreneurial endeavors.

Building a Truly Interdisciplinary Entrepreneurial Capstone Experience

The course launched this year is a three quarter-long interdisciplinary innovation and entrepreneurship-focused senior capstone experience. While the long-term vision for the course is to accept students from throughout the university's six colleges, in the initial cohort we chose to accept students from the colleges of business and engineering both because of the historical demand from students of these colleges, and also because of the logistical challenges described later in introducing cross-college curriculum. The course was designed to integrate Lean Startup

methodology with Agile Engineering and Design Thinking. Given this, the first quarter of this sequence focused on customer validation and needs-finding. In addition, students were pushed to begin prototyping early and were challenged to start working toward a minimum viable product that would allow them to achieve a measureable response.

Background: Establishing the Course

In establishing an entrepreneurially-focused interdisciplinary capstone course, we encountered several challenges:

- Administrative approval for teaching time, funding, etc.
- Making students aware of the new course offering and recruiting for the initial cohort.
- Creating a curricular vehicle that would allow students from both multiple majors and multiple colleges to enroll in the same course.
    - Cross-college credit hours.
    - Scheduling the class so that students from each college would not have other conflicts.
    - Locating appropriate and available space on campus.

Administrative approval for the course was sought nine months in advance of the intended launch of the course with deans from both the college of business and engineering expressing support for an additional interdisciplinary course. It was agreed that external support would be required, as there wasn't a funding source for project materials and supplies. In addition, a sufficient number of students per faculty member would need to be maintained. Given the range of expected projects, we believed that the minimum teaching team for this course would be three instructors, one from the college of business and two from the college of engineering, with expertise in both software and hardware. For this team, it would be necessary to have an initial cohort of at least fifty students, with at least sixty students desired by administration.

One subtle point related to the number of students per faculty is that the student/faculty ratio had to be maintained across both colleges based on the ratio of the teaching team. This was required because tuition is allocated to the individual colleges based on the weighted units taught to their home students. Therefore, the class had to roughly maintain the 2:1 ratio of engineering to business students to mirror the teaching team. This requirement necessitates the teaching team to give some forethought to both recruiting and team makeup and also presents an additional challenge that must be overcome before we look to expand the course to include additional colleges.

Marketing the course began the spring before the course was to begin, before external funding had been identified. Three information sessions were offered that focused on explaining the logistics and crediting for this non-traditional course, the process that would be followed, and team formation. During these sessions, students were given the opportunity to present ideas they had been considering for the course and outline the different skill sets they believed they would need to execute these ideas. The original intent was that these information sessions would serve as the basis for team formation and result in a pool of teams applying for the class the following fall. This process has been outlined for team formation for the Lean Launchpad course developed at UC Berkeley for their MBA program (Blank, Engel, and Hornthal 2014). Seventy-six students attended these initial information sessions, with various numbers and different people at each session. Through this process, we only had one team that actually formed, and the initial idea that resulted in team formation was not a technically feasible idea for the course, as the scale was too grand for a senior capstone course. We will examine and reflect upon the best approach for course marketing in upcoming years to understand if our lack of

success represents a difference between an undergraduate and MBA course, was because the course was new and teams will form earlier in the future with more institutional knowledge that the course exists, or represents a campus culture difference between our university and the one referenced above.

To address the curricular issues, we first utilized existing senior capstone course numbers and created special sections within those courses. This process enabled us to launch the course immediately and begin accumulating a track record of student projects that could be submitted as example projects when the full course would later be at the academic senate. This also helped us to temporarily bypass the process of trying to standardize a course across multiple colleges with different academic review processes and with different learning objectives for their existing senior project courses.

While it was initially a concern that students enrolled in the same course and with the same expectations from two different colleges would complain that they were getting different numbers of curricular units, we found that not one student complained about this difference. Students were excited that the opportunity existed and seemed pleased to be part of the experience, as opposed to worrying about credit equity between colleges. This was both a surprise and a relief and could be an indicator of how little value entrepreneurially-minded students ascribe to collegiate credits as opposed to entrepreneurial experiences.

Scheduling and class space represented the other large barriers for this course, as the calendars between students in different colleges don't always align. To exacerbate this challenge, the fact that we were teaching this course for an entire year required students to plan their schedules throughout the year to ensure they could continue to participate in the class. To address this issue, we scheduled the course on Monday and Wednesday evenings, as the majority of evening classes are general education classes that seniors have either completed or have flexibility in choosing. This strategy seems to have enabled the greatest amount of student participation. The classes meet each Monday for three hours. Wednesdays are reserved for class, but are primarily intended for meeting and work times for the groups by blocking out their schedules. Meeting in the evening also helps with room scheduling. We have been fortunate enough to utilize an open style classroom that was recently renovated specifically for entrepreneurial activity. This space consists of numerous whiteboards and rolling chairs and tables that enable us to configure the room each week based on the specific activity that we have planned.

Participants: Who Cares

While the goal for the course is to make it broadly available to students across each of the six colleges at Cal Poly, for the first cohort we chose to focus on the colleges of business and engineering. This decision was based primarily on the ability to solve curricular student and faculty credit issues within the university structure for two colleges, but also because student participation in CIE programming to date has consisted of approximately 85% representation from these two colleges. A breakdown of the number of students per discipline from the sixty-seven student cohort is shown in Figure 2.

PARTICIPANT COLLEGE & DISCIPLINE	# OF PARTICIPANTS	APPROXIMATE # OF GRADUATING SENIORS
College of Business (Total)	26	700
Business Entrepreneurship	22	37
Business Marketing	1	106
Industrial Technology	3	52
College of Engineering (Total)	40	920
Aerospace Engineering	1	58
Biomedical Engineering	3	69
Computer Engineering	9	71
Computer Science	4	86
Electrical Engineering	7	118
General Engineering	1	15
Industrial Engineering	1	69
Manufacturing Engineering	1	14
Mechanical Engineering	12	192
Software Engineering	1	26
College of Agriculture, Food & Environmental Science	1	930
Agriculture Business	1	162

Figure 2. Number of students represented in the initial cohort of this class both by major and college.

Our initial goal for each team was to have 3-4 engineering students and 2 business students (5-6 students per team). This goal was set based on the total number of students per team (larger teams tend to be difficult to organize and manage), ensuring that there were adequate students to do customer discovery interviews in pairs, and to ensure that enough engineering disciplines would be represented to have the requisite skill sets for the projects. Given this, we were targeting approximately 37% college of business students and 63% college of engineering students for the course makeup, which is close to what was achieved. Departments from across the college of engineering had relatively uniform representation by percentage of total students, with most having 5-10% of their seniors participating in this new course.

Initial discussions with the deans of the remaining four colleges has begun to reveal how we can expand the course to other students. These discussions indicate that scaling the teaching team will be one of the most difficult obstacles. While twenty-two students per faculty member for a senior project class is a large, but not unreasonable student/teacher ratio, the interdisciplinary nature of this class has not allowed the teams to be neatly divided up among the teaching team. Each team has required expertise from the other instructors on a regular basis, so each faculty member is at least partially supervising the entire cohort. Methods to handle this challenge, particularly as more disciplines are added, finding faculty with broad expertise, and also ensuring that each added teaching team is extremely comfortable working together in ambiguity (discussed in the next section) with other

faculty are some of the key barriers we have identified to scaling this course. We envision that, at a minimum, both vetting and training procedures for new faculty would be required, as well as working to develop an external pool of industry experts that could contribute as resources to the course sections.

Team Formation Process

Because we did not enter the fall quarter with established teams, team formation was incorporated as part of the course. We addressed this deficiency both by allowing students to pitch their ideas for the class after pre-approval of the topics with the teaching team, and by selecting approximately ten domains that we felt would provide fruitful areas for idea generation. Examples of the domains provided by the teaching team were virtual reality, biofeedback, on-demand sharing services, and tools for the maker movement.

Teams were formed over the first three weeks of the course. During this time, we introduced improvisational exercises during each class period that were designed to help students in the class meet and get to know other students and to aid in divergent thinking as time was allotted each week for domain-specific ideation. The guidance provided to the students was that in addition to finding a topic area that interested them, they should find colleagues that had similar goals for the class. This guidance was provided because team dynamics during a year-long, challenging course contribute as much to the student experience and success in the class as selecting the project that most interests them.

Some teams formed immediately during the first week, while other students struggled to form teams throughout the first three weeks. During the ideation sessions, which were segregated by domain topics, the teaching team interacted with groups and also individuals. Many students expressed anxiety over the uncertainty regarding their senior project and this anxiety was exacerbated each week for students that had not yet found a team. To guide the students through this, the teaching team had to devote many hours after class in the evenings and other times throughout the week meeting with individual students and working through their concerns.

An unforeseen challenge was that some students who came to the class with a project they were working on prior to the class did not want to accept new members into their group, even when those new members would be critical in providing the necessary complementary skill sets to accomplish the product or service design. We chose to take a zero tolerance policy on this and informed the students that they had the choice of either building a full team on their own, continuing to work as a partial team without taking part in the class, or accept additional students. In all cases, the students decided to accept the additional students and there have not been any problems with the teams based on this issue. This choice was made because we did not have any actual companies entering the class. There were a couple of small groups that had made minor progress, but it helped to set the tone very early that nobody in the class had yet earned the right to think of their team as a company. The existing ideas were at best unvalidated product concepts; we wanted each team to be clear that a full design and customer validation process was required before teams started to consider transitioning from idea/project to company. We also required teams to complete a team contract, which outlined their individual goals and responsibilities for the project. Teams did not assign specific “jobs” (e.g., CEO, CTO) as we expected all students to participate in decisions across disciplines. As the course progressed, however, students began to find and define their own roles within the team.

Curricular Design

The course was designed to combine elements from the Lean LaunchPad course (Blank, Engel, and Hornthal 2014), Agile Engineering, and Design Thinking. The goal was to take students through all elements of an entrepreneurial design experience, including listening to the customer, product ideation, customer development, rapid prototyping, minimum viable product development, and product test and validation. While we formulated a rigid syllabus based on this process (see Figure 3), we quickly realized that groups worked through the design process at very different paces. We maintained the structure and pace in the syllabus, and pushed each team to at each deliverable to update their status against the outlined process and defend their current designs. Groups that were further behind due either to taking more time up front to coalesce on a project idea, or had made significant pivots based on customer development, had to outline their current assumptions relative to the actual deliverable, and describe their next steps and timeline required for them to complete the steps necessary to validate these assumptions. Given that design is not a linear process, holding students to a linear timeline would have been inconsistent with everything we were teaching. At the same time, a balance had to be found to maintain accountability on the projects and also to understand when students had to take steps backward to move forward. Having a teaching team, as opposed to teaching a course like this alone, was incredibly helpful in managing these judgements, particularly given the team's diverse backgrounds.

Quarter 1

	SUMMARY TOPICS/EXERCISES	KEY DELIVERABLES
Week 1	• Research on companies and startups in the domain of interest	• Real Startup Deep Dive Paper
Week 2	• Domains of interest ideation • Intro to Lean LaunchPad (value propositions and customer segments)	
Week 3	• Finalize teams and domains	• Team contract • Initial concepts due
Week 4	• Intro to value proposition canvas • Customer archetypes	
Week 5	• Group presentations on initial value proposition canvas • Design concept activity	• Initial value proposition canvas
Week 6	• Value proposition canvas • Value proposition mad libs	• Initial customer interview list
Week 7	• Customer development interview skills	• Revised customer interview list and questions • Design concept update due
Week 8	• Business model canvas seminar and BMC risk assessment activity	
Week 9	• Engineering requirements	
Week 10	• Customer discovery debrief and BMC revision	• First customer interviews completed
Week 11	Final presentations and minimum viable products	Final presentations and minimum viable products
Week 12	No class – finals week	Low resolution design documentation

Quarter 2

	SUMMARY TOPICS/EXERCISES	KEY DELIVERABLES
Week 1	• Introduce design sprint #1 • Review of engineering requirements	• Second round of customer interviews
Week 2	• Working session for design sprint #1 • Project budget forecasting	• Updated BMC
Week 3	• Working session for design sprint #1 • Project scheduling	
Week 4	• Design sprint #1 presentations	• Revised MVP due • Prototype deliverable • Customer interviews
Week 5	• Introduce design sprint #2	• Revised BMC
Week 6	• Working session for design sprint #2 • Intellectual property	
Week 7	• Critical design review presentations	• Critical design review • Prototype revisions
Week 8	• Introduce design sprint #3	

Week 9	"Short pitch" coaching session	
Week 10	Working session for design sprint #3 Corporate formation overview	
Week 11	Working session for design sprint #3	
Week 12	No class	Final design document

Figure 3. Syllabus used for the first two quarters of the interdisciplinary entrepreneurial senior capstone course.

Lessons Learned

We have learned a number of important lessons regarding launching this course. These lessons are important to document both for this teaching team as we continue to revise and improve this course, and also for others in the community considering launching such a course. While extremely challenging in the typical organization structure of university and also with regard to managing such unstructured projects, the authors believe that courses such as this are a very valuable part of the students' culminating undergraduate experience. They challenge students to live through an ambiguous, interdisciplinary design experience that challenges their entrepreneurial spirit. Some will continue these projects and form companies, some will launch different entrepreneurial endeavors supported by the skills developed during this year, some will go on to be great intrapreneurs in larger companies, and others will discover that their interests lie in supporting, but not leading entrepreneurial efforts. With this in mind, however, the following activities require further thought and refinement for future years.

Improve Upfront Recruiting for the Class

While we followed a methodology that has been developed and implemented at another university, our inability to have at least half of the projects pre-defined at the start of the course made it difficult to devote time for each of the student teams that were struggling with opportunity identification at the beginning of the course. In addition to the course becoming better known on campus, one possible solution to this would be to introduce a junior level "needs finding" course that could serve as an ideation course immediately before seniors enroll in this capstone course.

Be More Assertive in Seeing Students with Ideas and Domains

We had several teams that required intervention from the teaching team to help guide them into an interesting domain. In retrospect, these students were quite happy once directed and had not explored the domain on their own because their lack of initial knowledge intimidated them. Once directed into it, however, their talents quickly made up for the knowledge deficit and they became energized by the opportunities available in a space that was previously unfamiliar to them.

Be Prepared for, and Build Time into the Syllabus for Teams to "Stumble"

It is difficult to imagine that teams won't struggle throughout the year, and particularly early on, with very nebulous projects. As noted above, we are discussing ways to reduce this with more upfront preparation, but it is not expected that we will eliminate this completely. It's important to ensure that activities in class allow the teaching team adequate time to meet with and advise student teams during these times of struggle. While some of this can be accomplished during office hours, it is uncommon for teams of 5-6 people to all be free during typical office hour times, given their disparate schedules. Allocating some time in class is strongly encouraged to account for this.

Some Students Will Work on Ideas that the Teaching Team Does not Consider to be Impactful

While our desire is that each team have the potential to launch a business at the end of this course, it's unrealistic to expect that 100% of twenty-one year olds that take an entrepreneurial senior capstone course could do this. While this seems obvious, the teaching team had to remind ourselves of this and ensure that at times we allowed students to continue on with ideas that would be difficult to impossible to commercialize, in the interest of making sure that they continued through an educational design exercise. We learn from our failures. The students and their colleagues in the cohort will learn from these failed project ideas, and we as a teaching team will learn from each failed project selection ways to improve our early ideation.

Conclusion

In conclusion, we have leveraged an existing senior capstone tradition and already approved capstone courses to quickly launch a full year interdisciplinary, entrepreneurial capstone design experience. The course is initially an effort that combines students from the colleges of business and engineering. Background in launching the course, participants in the first cohort, team formation, curricular design, and lessons learned to date are discussed with the goal of providing a point of reference for other institutions considering launching a similar cross-college curriculum.

Acknowledgements

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