Is It Senior Design or a High Tech Start-Up?

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Abstract
The Senior Design course taken near the end of an engineer's undergraduate tenure is increasingly recognized as a "capstone" activity, enabling these future professionals to apply their collegiate education and experience in a team environment to solving real world problems or to creating new capabilities. Ideally, Senior Design teams are also cross-functional, to broaden the projects and better replicate the professional world. In addition, there is a growing interest in linking Senior Design with entrepreneurial activities, even to the point of commercializing promising project results.

The Electrical and Computer Engineering Department of Florida Tech has structured its senior design course sequence to replicate many of the activities that would be appropriate for a start-up venture, or a corporate product line introducing a new suite of products. In addition to the traditional preliminary and critical design reviews and a demonstration of the completed project, students learn about the industrial new product pipeline and generate feasibility studies, business plans, prototyping, validation reviews, and launch collateral to support a "market introduction" of their product. Senior Design culminates with a public "trade show" held as a feature of the University's spring Open House for the families of interested high school students. Most of the teams span multiple departments, and this year one team spans two universities and two others are contemplating commercializing their products, utilizing Florida Tech's new business accelerator, Florida TechStart.

Background
The Florida Institute of Technology (aka Florida Tech) is a private university of about 3500 students located in Melbourne, on the high technology "Space Coast" of Florida, about 30 miles south of Cape Canaveral. The principal component of the university is the College of Engineering (CoE), which harbors about half of the total enrollment. The CoE offers both undergraduate and graduate programs. Within the College of Engineering are seven departments: Chemical Engineering, Civil Engineering, Computer Science, Electrical and Computer Engineering, Engineering Systems, Marine and Environmental Systems, and Mechanical and Aerospace Engineering. All of the departments except Engineering Systems, which currently only offers graduate programs, require their students to participate in Senior Design as part of their program core curricula. Each department managed their own senior design courses, and there was no formal or systematic interaction between the departments in this regard.

The Electrical and Computer Engineering (ECE) Department senior design course sequence comprised two consecutive courses taken during the senior year, in which students formed teams and took on engineering projects designed to exercise their technical, practical and teamwork skills. Most of the project teams would contain a mix of electrical and computer engineering

students. A few of the teams would span engineering departments at the university. For instance, there would always be a Mechanical Engineering vehicle team (formula race car, baja car, etc.) which needed electrical and computer engineering skills to develop gauge clusters, computer control systems, wiring harnesses, virtual dashboards, and so forth. There would always be an Aerospace Engineering plane or rocket project which needed electrical and computer engineering skills for data acquisition/analysis, communication, command and control systems.

Beginning in the Fall of 2002, several significant changes, decisions and events occurred in rapid succession and have had a dramatic positive impact on the nature and quality of the senior design program in the ECE Department and throughout the College of Engineering:

- The ECE senior design course context was changed to emulate a start-up enterprise
- Over $40,000 in NCIIA funding was acquired to support certain types of senior design teams
- The senior design course instructors across the College of Engineering elected to self-organize to better coordinate their courses, forming the Senior Design Coordinating Committee (SDCC)
- The School of Management elected to actively participate and support the senior design experience in the College of Engineering
- The ECE Department senior design course sequence was extended by a semester, to be three semesters in length
- The SDCC sponsored the first Student Design Day, a "trade show" at which all CoE senior design projects were put on public display in the gymnasium
- The first multi-university ECE senior design team was formed
- The first ECE senior design team decided to commercialize its project results
- The College of Engineering and School of Management collaborated to set up Florida TechStart, a business accelerator for the university
- The School of Management established the first general ledger for all CoE senior design teams, greatly improving financial management in this area

Context for the ECE Senior Design Sequence of Courses

Florida Tech was formed entrepreneurially in 1958 to provide much needed continuing education opportunities for the engineers working at NASA and related space companies at Cape Canaveral. The entrepreneurial spirit and culture at Florida Tech has continued up to the present. When a new professor took over the senior design course sequence, after spending a quarter of a century in industry, the architecture of the courses immediately took on a "new look". At the first class, the students are told that they have been recruited from college into a new start-up (a fictitious, "Florida Tech Ventures, LLC"), and that they have until April of the following year to form teams and conceive, define, design, develop, prototype, build, characterize, validate and prepare to launch a suite of new products, to be displayed at an all-important trade show. The students learn about the new product pipeline, technology roadmapping, business planning, the product-to-market cycle, design-for-X, project planning, management, execution and closure, and the whole product concept, including the development of launch collateral and participation in trade show events.

As part of the venture ambiance, "Classes" were replaced with "all hands meetings". "Lectures" were replaced with OJT (On the Job Training). The "instructor" became the start-up's President, CEO, CTO and CSO. The "graduate teaching assistant" assigned to the course became the COO, CFO, Chief Scientist and Lab Director. A simple management hierarchy was installed, and there were meetings with the project leaders to discuss management as well as project and technical topics.

The goal of putting the course sequence into this context has been to make our graduates as "plug 'n play" as possible. The value proposition slogan for Florida Tech engineering has evolved to be that "you can learn engineering at a number of places; you do engineering at Florida Tech". (For example, our ECE students design and build their own computers as freshmen.) We routinely survey recent graduates and also their employers, and over the next few years will determine if this strong industrial, entrepreneurial flavor to senior design does shorten the time for new college grad employees to become productive in their careers.

Senior Design Course Content

It became apparent that in this context, the amount of technical and programmatic material handled in the senior design sequence was so great that it was adding technical and schedule risk to the successful completion of many of the projects. Project teams which needed to secure external funding to support the materials and services needed to be purchased for their projects were even more pressed for time. The current run rate for project expenses across the College of Engineering is about $100,000 per year. Most of this money comes from grants and external sponsors and donors for the projects, and most of the sponsors and donors must be discovered or cultivated annually by the teams needing the funding.

On this basis, it was decided to add a semester to the ECE senior design sequence of courses. The sequence now begins in the spring semester of the junior year and proceeds through both semesters of the senior year. The junior design course is a one credit course, and the two senior design courses are three credits each. Junior design includes project and team selection and culminates with a preliminary business plan and a display of the emerging project at the Student Design Day trade show.

The first semester senior design course is the semester for design, ending approximately with the Critical Design Review (CDR). The second semester senior design course is the semester for building, validating the product, preparations for a launch, and a display of the finished product at the Student Design Day trade show.

New high tech start-ups often have the attributes of a skunkworks, with virtually no structure or documented systems for getting things done. On the other hand, an expanding product line in a corporate setting often has a surplus of structure and documented systems and procedures to follow. The ECE senior design course sequence emulates a hybrid of these two environments, to prepare the students for participation in either. More succinctly put, we expose the students to detailed systems, then relax them in practice somewhat to encourage creativity and also to account for the fact that this experience is superimposed on typically four or five other courses the students are taking, plus all of the other senior year activities and events. Even with this,

many of the students become enthusiastically involved and average 20 hours a week or more working on some stages of their projects.

Below is a summary of the senior design course sequence content, expressed as the topics covered and course deliverables required of the students and teams:

Junior Design Topics –

- Team Formation and Project Selection
- Project and Product Development Basics
- Feasibility Studies
- Project Funding and Finances
- Business Planning
- Trade Show Preparation

Junior Design Deliverables –

- Project Feasibility Study
- Preliminary Business Plan
- Trade Show Booth
- Project Website
- Weekly Individual Activity Reports, once teams are formed

The feasibility study touches on technical, schedule, financial and "marketing" feasibility. The business plan is not complex; it has minimal financial content, focusing on top level specs, the product value proposition, competitive analysis and risk awareness.

Fall semester Senior Design Topics –

- Product to Market System Details
- Project Planning, Management, Execution and Closure
- Product Design
- Design-for-X
- Risk Management and Mitigation
- Engineering Ethics

Fall semester Senior Design Deliverables –

- Final Business Plans
- Detailed Gantt chart
- Preliminary Design Review (PDR) and Documentation Package
- Critical Design Review (CDR) and Documentation Package
- Project Website
- Individual Project Journals
- Weekly individual Activity Reports

The fall semester is heavy in documentation, as it should be. All the content is lifted directly from industry best practices (the instructor is also an industrial consultant in these areas). The deliverable due dates are set by the project Gantt chart plans, and not by a rigid class "schedule".

Projects completing their CDR before the end of the semester proceed to the build stage of their projects during the fall semester.

Spring semester Senior Design Topics –

- Proof-of-Concept Prototyping
- Building and Validating the Product
- Whole Product Concept and Launch Collateral
- Trade Show Preparation

Spring semester Senior Design Deliverables –

- Detailed Gantt chart
- Proof-of-Concept System Level Prototype
- A Product that Works to Spec
- Validation Review and Documentation Package
- Launch Collateral
- Trade Show Booth
- Team Web Site
- Individual Project Journals
- Weekly individual Activity Reports

The spring semester is heavy in building and testing. The validation review is simple in concept, but not necessarily easy. It answers the questions "what did you say it was going to do?", "what does it do", and "how do you account for the difference?". For launch collateral, teams develop and deliver their choices from a list of possibilities. The choices range from applications notes and instruction manuals to marketing brochures and websites, journal and magazine articles, to patent disclosures and site sellers. The trade show booth is displayed at Student Design Day, which this year will be held on a Friday and a Saturday. The Friday trade show is for grading, judging, and exposure to students, faculty, the public, and various departmental and college level advisory boards that purposely schedule events for that day. The Saturday trade show will be part of the university Open House event, with approximately 2000 high school students and families from all over the country attending the trade show, plus the general public. The last week of the semester is spent doing informal lessons-learned discussions, covering the trade show, the projects and the course in general.

Coordination with Other Departments, Schools and Universities

The ECE senior design course sequence does not exist in a vacuum. There is heavy coordination in several dimensions. The instructors of all the senior design courses meet regularly as the Student Design Coordination Committee (SDCC) to collaborate and coordinate the courses, to address common opportunities and issues, to set CoE policy regarding senior design, and to cross-pollinate and share best practices. The electrical engineering, computer engineering, mechanical engineering and aerospace engineering programs are completely coordinated, having the same three course schedule. The other programs have one- or two-semester programs which also are synchronized with the flow. There are several common sessions where all classes meet in the same auditorium. These meetings are held at the beginning of junior design, to encourage and facilitate the formation of true cross-functional teams, and again periodically throughout the

senior year, typically for invited internal or external speakers delivering information and wisdom on topics of common interest.

The SDCC plans and coordinates (with much help from volunteering student honor societies) the Student Design Day event, and works many common issues, often relating to finance and fund raising. It sets policy, such as requiring all CoE teams to get access to and learn Microsoft Project as our standard software for project planning. Since the advent of the SDCC, the fraction of multi-departmental ECE project teams has doubled.

The School of Management (SoM) also participates in the SDCC. In addition to the traditional high level of cooperation between the College of Engineering and the School of Management, the School of Management has three specific interest areas regarding CoE senior design. First, several senior design projects are used for case study and market study purposes by some SoM courses. The marketing students work with the teams, do their study, and share the results with both the team and the senior design instructor.

Second, there is a decided entrepreneurial spirit in our School of Management, and there is engagement with senior design teams desiring to commercialize their products through Florida TechStart, our university business accelerator, which was founded and is managed collaboratively by the SoM and the CoE. Finally, our senior design course financial system is being heavily supported by a series of accounting students who are setting up, managing, and improving a general ledger system used by the project teams and course instructors to manage senior design finance.

In industry, it is common practice for product development teams and their supporting functions to be scattered across several company sites. It is also a common practice for some new products to be developed in collaboration with the early adopting customers, in different companies at different locations and perhaps even in other countries. A grant was secured from NCIIA to support providing this type of experience to selected senior design teams. Our partner in the grant is the Rose-Hulman Institute of Technology, in Terre Haute, Indiana, about 1000 miles from Florida. This year we have one team, of approximately 20 students, with team members split between the two universities. They are working on a project focused on a system for the wireless tracking of materials and people. A university in Switzerland has indicated an interest in a similar arrangement. An Aerospace Engineering team is currently collaborating with a team from the Indiana Institute of Technology, and there is consideration of doing a three-university senior design team in the future.

How About a Real, High Tech Start-Up?

What if a senior design team wants to go from emulating being part of a start-up to actually starting up a company to take its senior design "product" to market? Florida Tech is prepared to support this type of activity, and as of this writing, three current or recent projects are in some stage of being productized for commercialization. Florida TechStart is a business accelerator for high tech ventures. It was opened in October, 2003, and is housed in the engineering building. Student teams interested in an entrepreneurial path work directly with Florida TechStart staff to make the necessary connections to help make their dreams a reality.

An additional resource is the array of entrepreneurial courses offered by the School of Management and by the Engineering Systems Department in Engineering. These courses cover the range from entrepreneurial finance to tactical and strategic marketing to business planning and even to how to secure SBIR and other seed money grants. Entrepreneurial certificate curricula are being developed, and graduate and undergraduate degree programs are in the planning stage. Further, an NCIIA grant has been received which provides funding to senior design course projects taking this exciting path.

The Products We Develop

There are approximately 40 senior design projects in the College of Engineering every year. Of these 40, the typically 70 – 80 ECE senior design students are team members of about 12-14 teams. The demographics of nearly all of these teams span departments or universities. This year's projects are:

- A flying submarine
- A compact scanning tunneling microscope
- A wireless materials tracking system
- A vertical take off and landing airplane
- A transponder system for tracking underwater creatures
- An autonomous robot utilizing GPS, sonar and mechanical sensing systems
- A wireless system for downloading DVDs from a computer to a vehicle audio/video system
- A rocket which sprouts wings and returns to earth as an airplane
- An advanced robotic wireless control system
- An automated, closed-system greenhouse
- A voice recognition system trained for specific words
- A small hovercraft
- A fiber optics system for weighing moving trucks on the highway
- A formula race car

What Happens Next?

Most of the senior design course system attributes described in this paper are new, have only happened once, and generally have not yet been in existence long enough for their impact on student post-graduate performance and success to be meaningfully measured. The only measured data so far has been the student surveys given in each course at the end of every semester. Since the inception of the changes catalogued in this paper beginning in the fall of 2002, the student evaluation of the ECE senior design courses has steadily improved from an already high rating, indicating that the students at least perceive continual improvement of the course context, content, delivery and results.

Some elements of the overall program are expected to grow, such as multi-university teaming. Three people in the Development organization of the university are now assigned to support senior design funding acquisition, and an endowment for the projects is being developed, all of which should dramatically reduce funding issues. Other elements of senior design, such as the Student Design Day event and the financial general ledger, are expected to continually improve as we add to our experience and lessons learned.

Conclusion

Over a short period of time, the ECE senior design course sequence has been transformed from a traditional, one year course to a three semester, high tech start-up emulator with significant external funding and an abundance of true cross-functional teams spanning departments, schools and universities. An entrepreneurial spirit is beginning to pervade the culture of the course, and several teams are already working towards becoming true start-ups. Improvements in student satisfaction with the course sequence have been quantitatively measured and are significant.

At the same time, all the departmental senior design courses of the Florida Tech College of Engineering have been transformed from a set of fairly independent, autonomous courses to an integrated, cross-coordinated organic shared curricular experience, complete with large public events and shared policies and course management systems.

The circumstances driving these changes are a synergistic confluence of independent decisions to shift faculty assignments, seek senior design funding, coordinate senior design courses, start a business accelerator and, on the part of the School of Management, to get involved with engineering senior design. The net result is as outlined in this paper.

Though it is too early to quantitatively assess the bottom line of the effects of these changes (student career satisfaction and success), such measurements will be done. In the meantime, there is general agreement of the course instructors, and also departmental and CoE administrators, that all of the changes have been beneficial and are already driving the right results.

Bibliographic Information

As the ECE senior design course sequence is a "doing" experience, information needed by the teams and projects is transmitted by means of meeting notes, much as in industry. There is no textbook assigned for any of the courses. However, typical of the texts which provide good reference information for the purposes of the instructor are:

1. Barry Hyman, Fundamentals of Engineering Design (Upper Saddle River, N.J.: Prentice Hall, 2003)

2. Daniel L. Babcock and Lucy C. Morse, Managing Engineering and Technology (Upper Saddle River, N.J.: Prentice Hall, 2002)

Biographical Information

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