

Entrepreneurship in Capstone Design Using Interdisciplinary Teams and a Business Plan Competition

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Abstract: Mechanical Engineering seniors at Grove City College participate in the college-wide business plan competition as one of their Capstone Design requirements. Capstone students work on teams focused on product development – including conception, design, market surveys, manufacturing, and production planning. Interdisciplinary teams include about six engineering students and one or two business students. They work together on the project during both the fall and spring semesters. A formal business plan is developed and submitted to the Annual Business Plan Competition near the middle of the spring semester. The plan is presented to judges from businesses near the end of the semester. Entrepreneurial topics are taught in required coursework, including the fall and spring semester Capstone Design courses and Engineering Economy. Topics specific to writing a business plan are included in the latter course. Many students also take a one-credit course on writing business plans which is offered by the Business Department. Results of the competition indicate the success of the program. In 2004, mechanical engineering teams placed second and third in the competition, although they comprise less than 5% of the student body.

Introduction: Grove City College's Engineering Entrepreneurship Program is integrally tied with the senior Capstone Design Programs (in the Mechanical and Electrical Engineering departments) and the college-wide Annual Business Plan Competition (sponsored by the Business department.) Figure 1 illustrates the relationship between the three programs. Entrepreneurial topics, including cost estimation and financial performance prediction, were included in the senior design program for many years. The advent of the Business Plan Competition in 2003 provided a new opportunity for engineering students. A cooperative effort between the engineering departments and the Business department led to the creation of the Engineering Entrepreneurship Program. Business students and engineering students work together on cross functional teams to design a product, investigate market opportunities, plan for production, predict financial performance, and write a comprehensive business plan for the competition. Guidance and instruction for the business plan are taught in Engineering Economy (a required senior-level course) and the Business Planning course offered by the business department.

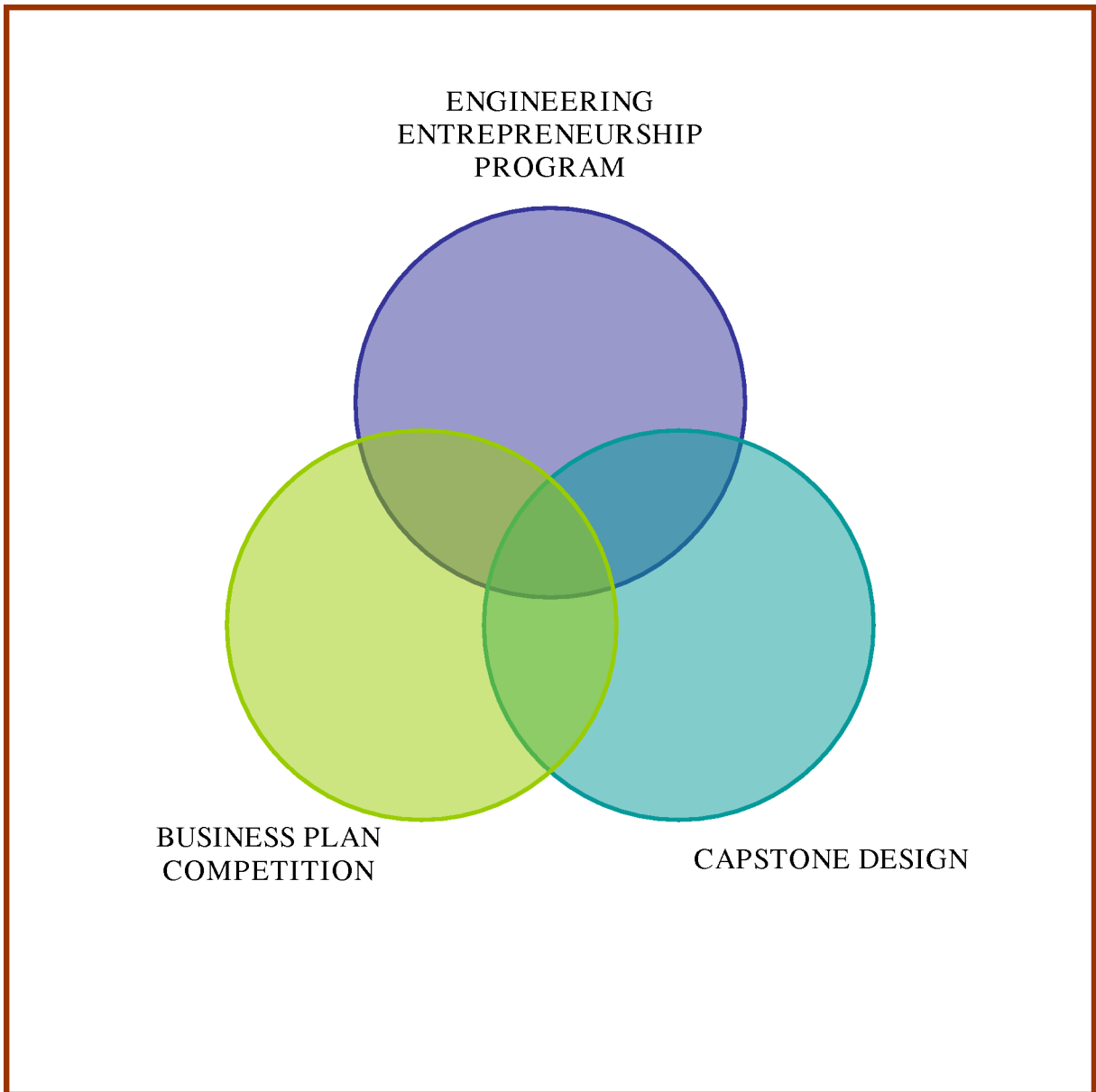


Figure 1 Relationship of the Engineering Entrepreneurship Program to Capstone Design and the Annual Business Competition

The goal of the program is to teach entrepreneurial skills to engineering students in a hands-on product development environment that mimics the real world. Two key factors help achieve this goal in an effective and efficient way. First, the excellent cooperation between faculty members in different departments is a significant asset. Second, use of existing programs (Capstone Design, the Annual Business Competition) leveraged the expertise of the faculty involved and provided a well-established structure for the new program. Although comprehensive assessment tools are not yet fully implemented, early metrics indicate that the program is very successful. Judges of the 2004 Business Plan Competition were very impressed with the quality and comprehensiveness of the engineering entries.

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Significant features of the Engineering Entrepreneurship Program include:

- The program is a required part of the Mechanical and Electrical Engineering programs. All engineering seniors participate through their senior design project.
- No new courses were required to implement the program. This eased the workload of inaugurating a new program and also improved its quality.
- In the program's first year, engineering teams placed second and third in the business competition, despite representing a small minority of entrants.

Brief Review of Other Engineering Entrepreneurship Programs: The importance of teaching entrepreneurship to engineers is widely recognized. Cassel¹ provides a good discussion of the relationship between engineering entrepreneurship and global competitiveness. Engineers, and in particular, entrepreneurial engineers, play a vital role in our nation's economy and competitive edge. Many engineering schools are including entrepreneurship topics at the undergraduate and graduate levels. This is accomplished with entrepreneurship courses, business incubators, business plan competitions, or a combination of these. In many -- if not most -- engineering programs, entrepreneurship courses are optional. For example, The University of Pennsylvania's School of Engineering and Applied Science offers a two-course sequence in engineering entrepreneurship.¹ The courses are offered as non-technical electives, and have proved very popular at Penn. Designed for engineering students with little background in business, the courses focus on roles and tasks engineering entrepreneurs must face.

The Cooper Union also offers a course in Engineering and Entrepreneurship.² Guest speakers are a critical component of this course. Students have the opportunity to hear entrepreneurs describe their experiences and provide advice. By the end of the semester, students are required to submit a business plan.

The University of Central Florida offers a three-course Engineering Entrepreneurship Program based on a technology incubator.³ Coursework includes Engineering Entrepreneurship, High Tech Product Strategy, and Technology Commercialization Strategies. The program is based on a "hands-on" approach in which students work on teams to develop a viable business plan. Pedagogical approaches include case studies, class discussions and guest speakers. The program has resulted in the growth of technology enterprises in the central Florida region.

A more traditional approach is taken at The University of Colorado at Boulder, which offers a one-semester design course which includes an emphasis on product development and entrepreneurship.⁴ Students work on teams that design, build, and test a new product, including manufacturing costs, profitability forecasts, and raising capital. The course appears to be a particularly well-implemented version of a more traditional approach to teaching engineering entrepreneurship. The program resembles Grove City College's Capstone Design prior to 2003, but on a smaller scale.

A business plan competition is used at San José State University to teach entrepreneurship to engineering students.⁵ This is a year long program. The competition takes the form of a New Venture Fair in December, followed by the SJSU Silicon Valley Business Plan Competition in June. A grant from Hewlett-Packard provided the funding and motivation for several student E-teams, which were required to develop business plans and a working prototype of a product related to mobile computing. Students and representatives of startup companies and other organizations in the area displayed their projects at the New Venture Fair. The year-long sequence enabled student teams to better prepare for the June business competition.

MIT has offered a very successful business plan competition for the last sixteen years. The \$50k Business Plan Competition invites teams of students to submit plans for review by a panel of judges. Mentors and other resources are provided to assist each team as they prepare their plans. The program has led to the founding of 60 new companies with a combined total worth of more than 10.5 million dollars.⁶ The success of MIT's program has proved to be an excellent model for other institutions striving to develop business competitions.

Overview of Entrepreneurship in Senior Design: Two notable differences set the Engineering Entrepreneurship Program at Grove City College apart from the programs discussed above.

1. The Engineering Entrepreneurship Program is mandatory for all engineering seniors.
2. No new courses were required -- the program integrated several existing courses.

A mandatory program means that all engineering seniors receive the benefits of participation as a requirement for senior design. Building the program on existing coursework made implementation of the program easy, and helped avoid mistakes reported by other programs. The real key to success was the level of cooperation between faculty in the Business, Mechanical, and Electrical Engineering departments.

History of Entrepreneurship in Mechanical Engineering at GCC For many years, mechanical engineering seniors at Grove City College have worked on teams to design a product and address its economic feasibility. Senior projects were completed within the framework of a product realization process which included customer surveys, market definition, and a complete economic analysis demonstrating the feasibility and potential profitability of the project. Technical design work included detail drawings, a working prototype, manufacturing process plans, and plant layout. Capstone Design projects were comprehensive, spanning two semesters and several courses. Each team developed a fictional corporation, originally to provide a framework for making technical decisions. For example, a particular part might be made by sand casting, investment casting, machining, or welding, with the proper choice depending on economics. The corporate identity allowed factors such as production quantity, lot size, in-house capabilities, etc. to

be included in the decision making process. These factors allowed the faculty to address the ABET requirement for real-world constraints.

This approach, while good, was still less than ideal. All work was completed by mechanical engineering students, making the term “cross-functional team” somewhat dubious. Business-related topics were taught by engineering faculty, not business faculty, and there was no interaction between the two departments. In 2002, seeking to improve the Capstone Design experience, a dialog began between the Business and Mechanical Engineering departments. It turned out that the business department was initiating a college-wide business plan competition that appeared to hold potential for a collaborative effort. Further dialog included a business faculty member in charge of the business plan competition, the engineering faculty member teaching Engineering Economy, and the faculty members in charge of senior design for the Mechanical and Electrical engineering departments.

The first year the business plan competition was implemented, 2003, mechanical engineering students were strongly encouraged to enter. Course content of Engineering Economy (ENGR-402) was modified to include elements specific to writing a business plan. Further, student teams were encouraged to enroll at least one team member in BUSA-466, Business Planning, which teaches students how to prepare and write a business plan. Business students were encouraged to join the engineering teams. Unfortunately, engineering students did not choose to enter the competition. A more formal approach was apparently required.

Faculty in the Mechanical Engineering and Business departments worked closely to develop a successful strategy. Four key items emerged: Capstone Design teams would be required to enter the business competition; the business department would facilitate matching business students with the engineering teams; business plans would be emphasized and required in ENGR-402, Engineering Economy; and at least one student from each cross-functional team would enroll in BUSA-466, Business Planning. The Mechanical Engineering faculty enthusiastically supported the program, which was fully implemented in the 2003-2004 academic year. The Engineering Entrepreneurship Program was born.

The Engineering Entrepreneurship Program: As in previous years, the Capstone design teams and projects were defined early in the fall semester. Soon afterward, the Entrepreneurship program director met with Mechanical Engineering students to describe the business plan competition and to inspire interest. By mid-semester, he held meetings to mate business students with the engineering design teams. Each design team made a brief presentation of their project to the business students. Business and engineering students were provided an opportunity to mingle and discuss the merits and potential for each project. In some cases, the match was finalized that evening. In most cases it was the beginning of dialogs between the students that lasted for several weeks. One project that was less appealing to the business students required faculty intervention to finalize the team. Each design team then consisted of about seven engineering students and from one to three business students.

In the spring of 2004, all of the business students, and some of the engineering students, enrolled in the Business Planning course. This class was taught by a professor in the Entrepreneurship Program, and included talks by successful entrepreneurs and venture capitalists. The course met twice per week: once for general instruction and once with the instructor for individual coaching. Students had a mentoring entrepreneur to coach and advise them during the plan construction and review it as part of a panel at the conclusion of the independent study. This course was not specific to high-tech business plans, and the engineering teams were a small minority of the class. All members of the class were required to submit business plans to the competition. The course was not a requirement for entering the competition, but was generally a key element to success.

Engineering Economy is a spring semester course that is required for both mechanical and electrical engineering seniors. The focus of the course was engineering economy, and emphasis was placed on the development of a complete economic analysis -- considering not only the time-value-of-money, but also direct/indirect costs, economic forecasting (optimistic and pessimistic), and expected rate-of-return. The students were exposed to methods used to evaluate a person's strengths and weaknesses. Once these are known, team member roles could be better determined, optimizing the team. Tools such as the Myers-Briggs Type Indicator were used. Finally, students attended a lecture presented by an entrepreneur that recently sought adventure capital funds. His business idea was an exciting application of new technology in the fast food market. His excitement and obvious technology savvy sparked interest and enthusiasm in the students.

First Year Results The results of this new endeavor were very encouraging. For the 2004 Annual Business Plan Competition, two of the engineering teams were selected to compete in the finals, and eventually placed second and third overall. The evaluators were impressed by the concepts, the content of the business plan, and the oral presentation (part of the final competition). One remarked that if the business plan would have crossed his desk and resulted in a formal presentation, he would have found it hard to deny funding. But more importantly, the students involved were excited about the possibility of working on a startup team, and had a fundamental baseline of useful knowledge and skills.

Lessons Learned Senior design faculty in the engineering departments must be committed to the entrepreneurship program to make it work. This was an important lesson learned the first year. The Mechanical Engineering department had enthusiastically endorsed the program, and fully participated in all events for the entire year. The plans for all three projects were well received, and two made it to the finals of the competition. The Electrical Engineering department was more passive, and did not participate in any of the activities during the fall semester. Support was essentially limited to that provided in the Engineering Economy course. The business plans submitted were very weak, and contrasted sharply with those of the Mechanical Engineering students. The following year, the Electrical Engineering department fully

participated in the entire program, and even requested additional guest lectures from the Business department faculty.

Capstone projects are not selected on the basis of how successful the resulting business plan will be. Both the engineering and business faculty agree that the primary benefits of the program do not hinge on the success of the business plan, but on what the students learn from it. The skills and discipline required to write a business plan are transferable to many other situations. Interviews with graduates indicate that writing proposals or “business-type” plans are a part of every day life. Some of the Capstone design projects are very amenable to successful business plans, while others are less so. Nonetheless, the engineering teams have submitted some extraordinarily sound plans.

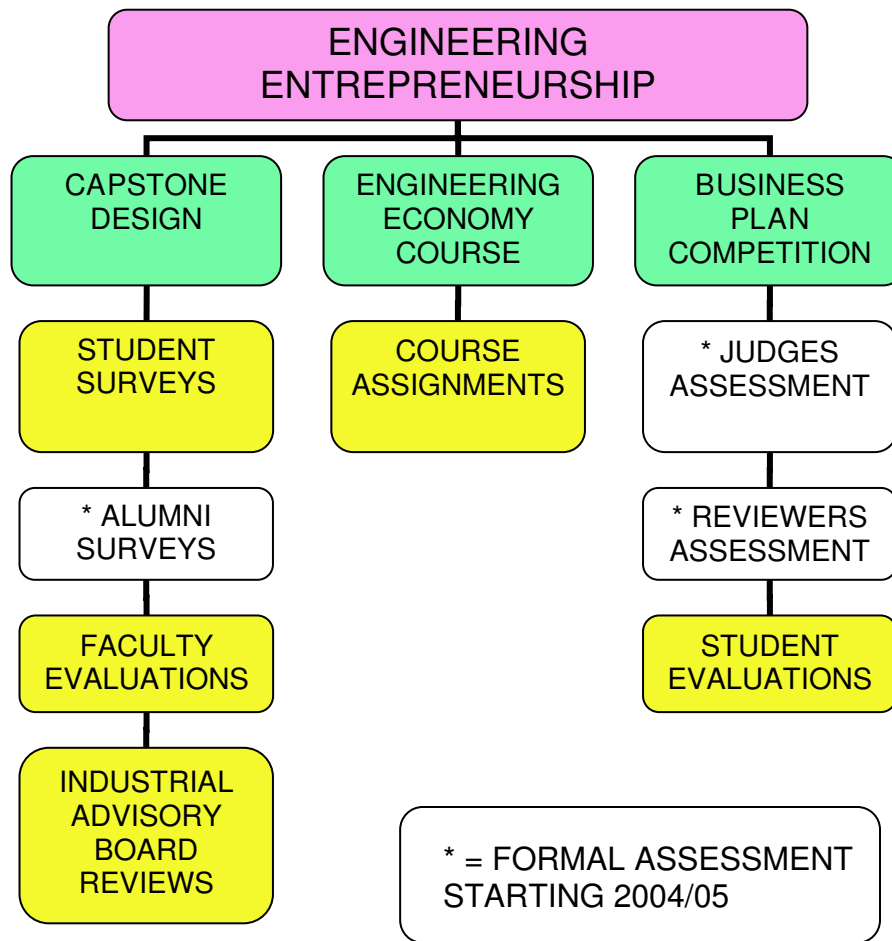
The Grove City College Annual Business Plan Competition: The Annual Business Plan Competition is open to all Grove City College students, who may submit team or individual for-profit or non-profit plans. The competition is sponsored by local industries and the Grove City College Entrepreneurship Program, and winners receive significant cash awards. For the 2004 competition, the awards were \$4,000, \$2,500, \$1,500, and \$500 for 1st through 4th place, respectively.

Each entrant submits a written plan that is read and evaluated by entrepreneurs and small business owners. From these evaluations, finalists are selected to present their plan to a panel of judges in a public forum. The panel, chaired by a college faculty member, judges the plans on completeness and quality, viability of the business, originality of concept, innovativeness of the concept, probability of implementation, etc.. The assessments of the judges are based solely on the presentation.

The Business Plan Competition is one element of the college’s Entrepreneurship Program. The program is recognized for its success. The United States Association for Small Business and Entrepreneurship recently selected Grove City College’s Entrepreneurship Program as one of two finalists for the 2005 USASBE National Model Undergraduate Entrepreneurship Program Award.⁷

Assessment: Currently, most assessment of the Engineering Entrepreneurship program is conducted on at the elemental level, within each of the different courses involved. An overall program assessment strategy is being developed, and should be implemented (at least partially) for the 2004/2005 academic year. One very positive indication of the strength of the program is the reaction of the business plan judges to the engineering teams’ plans. Judges indicated that the engineering teams were very well prepared for the competition, with comprehensive data relating to the design, manufacture, marketing, and predicted financial performance of their product.

The Engineering Entrepreneurship Program assessment tools include student surveys, faculty evaluations, feedback from the department industrial advisory boards, alumni surveys, and the business plan competition judges. These tools are not yet fully in place. Students have the opportunity to comment on the program as part of their course evaluations, but questions specific to the program have not yet been added. These will be



added for the 2005/2006 academic year. In general, student comments have been very favorable, and students have been pleased with the program. The only negative comments involved the additional time required to complete the business plan. This issue was addressed for the 2004/2005 academic year by restructuring the Capstone Design assignments to provide additional time during the period that students are writing the business plan.

Both the faculty and the industrial advisory board have provided input on an informal basis. Both groups were quite pleased with the program, primarily based on the outcome of the 2004 Business Plan Competition. More formal tools are being developed to obtain written evaluations on an annual basis from each group.

Alumni surveys have indicated a strong need for teaching entrepreneurial skills. Our first alumni to participate in the Engineering Entrepreneurship Program graduated only a few months ago, and have not yet been polled. As this group grows over the years, we expect to receive more feedback.

While the overall Entrepreneurship Program of the college has several key assessment tools, no formal assessment procedure has been used in the past for the Annual Business Plan Competition. The Entrepreneurship Advisory Executive Committee has recommended a formal assessment for the competition, and tools are currently being developed. Beginning with this year's Annual Competition (April, 2005,) a formalized assessment process is being implemented. All event participants including students, reviewers, and judges will be invited to complete an electronic assessment immediately following the event's competition. Additionally, members of the audience, including the general public, will have the opportunity to share their comments through a written evaluation. An action plan and timeline for the 2006 event and beyond will then be developed to address those observations and suggestions having merit. This process will further ensure a quality learning experience for not only the students, but for all participants in the Business Plan Competition at Grove City College.

Anecdotal evidence provides support that the competition is a valuable experience for students. Three entrants over the last two years have actually started their own companies. One of these reported that his company would not have been possible without the knowledge and experience he gained in the Business Plan Competition.

Conclusion: Entrepreneurial skills are important for the engineering graduate. This is true for all engineers, not only those involved in startup companies. Cost estimation and the ability to predict financial performance are required on virtually all real-world projects. The ability to write a successful business plan implies an ability to write other types of successful proposals. Participating in an entrepreneurial-oriented senior design project gives graduates a deeper understanding of real-world constraints.

The Engineering Entrepreneurship Program at Grove City College is unusual in that it is a required part of the curriculum -- all senior mechanical and electrical engineering students participate. The program, based on a well-established Capstone Design program and the college's recently introduced Business Plan Competition, used existing courses, resources, and faculty. Engineering students and business students work together on cross functional teams to design a product, investigate market opportunities, plan for production, predict financial performance, and write a comprehensive business plan. The plan is submitted to the Business Plan Competition along with entries from many other departments across campus. The effectiveness of the program is demonstrated by the high scores and complimentary comments of judges in the Annual Business Competition. In the first year, Engineering Entrepreneurship Program teams took second and third place overall in the competition.

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