

# Framework to Implement Engineering Senior Design Clinics to Enhance Industry Collaboration

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Senior design capstone projects for engineering students are essential components of an undergraduate program that enhances communication, teamwork, and problem solving skills. Capstone projects with industry are well established in management, but not as heavily utilized in engineering. This paper outlines a general framework that can be used by students and faculty to create a strong, industry-based senior design capstone course. The framework has been established over the past 17 years at The University of Toledo College of Engineering and has been applied to over 90 projects in the Mechanical Engineering Department. This paper outlines the course framework, a discussion of the resources required, overviews of typical industry projects, a discussion of evaluation criteria, and a discussion of the benefits.

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## Introduction

The capstone course is well established in management and strategy teaching, but not as heavily utilized in engineering<sup>1</sup>. The Accreditation Board for Engineering and Technology (ABET) emphasizes the need for engineering courses that build teamwork, communication, and project based skills. The capstone courses aid in building and enhancing these skill sets. This paper provides framework and support structures, including a design clinic, for implementing engineering capstone projects that are interdisciplinary and industry based. The framework provides a systematic approach and is displayed in Fig 1.

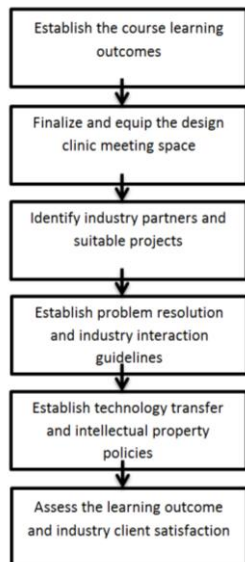


Figure 1. Framework to implement senior design clinics

This framework enhances industry collaboration as it provides a systematic approach to establish a common meetings space, problem resolution guidelines, addresses technology transfer, and assesses client satisfaction levels. In addition, this paper relates the course to ABET criteria and provides insights from students that have completed the course. The framework has been established over the past 17 years at The University of Toledo College of Engineering that has applied to over 90 projects in the Mechanical Engineering Department. Advantages of the capstone course and design clinic are that it facilitates a deep as opposed to surface learning and enhances communication skills. As engineers are called upon to work in cross functional teams, the skills learned using this method will place them in a stronger position to be successful as they move into the workforce upon graduation. In this paper, the author draws upon his experience integrating the capstone course and senior design clinic into the curriculum.

## Need Assessment

There appears to be a general lack of ability by students to function on teams and that engineering faculty cannot afford to take a chance to leave team building processes to students without some guidance<sup>2</sup>. A well-developed capstone course can aid students in developing these skills. Several research studies have been conducted in this field. In the United Kingdom, a study was conducted that discussed the development of an engineering design center to integrate industry and academia<sup>3</sup>. This provided a dedicated center for students and industry to interface for civil engineering design projects. From a computer science standpoint, a

study was conducted that discussed the win-win aspects for students and industry in capstone projects at North Carolina State University<sup>4</sup>. This paper focused on capstone projects to develop software systems for clients in North Carolina and discussed the results of an informal student survey. Overall, the students were very satisfied with the design projects and skills learned from the project. The justification and objective of this study was to demonstrate the benefits of the capstone course and senior design clinic for engineers and provide a framework for other universities to implement a similar program.

As a whole, these studies emphasize and demonstrate the benefits of industry related projects and the usefulness of design centers. This paper builds upon the concepts and relates them to the senior design capstone course and the design clinic at The University of Toledo by providing a framework to implement a similar program.

### ***Course Description***

The catalog description of the Mechanical Engineering Senior Design course is provided in the 2009-2010 catalog of the University as follows:

“Students work in teams using knowledge gained in earlier courses to solve real design, manufacturing, and operational problems relevant to industry. Oral and written communications with participating companies, as well as teamwork, are stressed. Other topics include patents, product liability, safety, ethics, and design for manufacturing.”

One faculty member serves as Course Director and is in charge of all administrative aspects of the course, including identifying the projects to be conducted by the students. Each group is supervised by a Faculty Advisor (Project Technical Advisor) and a Client Advisor. The Project Technical Advisor and the Client Advisor meet with their groups on a weekly basis.

Activities during the class meetings may typically include lectures and guest lectures on topics such as the design process, creativity, product liability, patents, and the business world. The frequency of the class meetings is determined by the Course Director. Attendance is taken at the beginning of each class period. Part of the grade is determined by attendance. Students are responsible for all materials, announcements, schedule and grading policy changes discussed in class.

The following is a list of the course outcomes; many are tied to ABET criteria:

1. To be able to work in self-directed teams.
2. To be able to communicate your work to others.

3. To be able to create product specifications based on customer needs while recognizing environment, economic and societal factors.

4. To be able to perform a design of a system or product based on product specifications.

5. To be able to generate design alternatives.

6. To be able to evaluate design alternatives using both analytical approaches and engineering judgment.

7. To be able to use engineering software packages in design activities.

8. To be able to build a prototype within a specified time period and within a budget.

9. To be able to test a prototype and compare its performance to design specifications.

10. To be able to understand the ethical responsibility of an engineer in design.

### ***The Senior Design Clinic***

Joint ventures between educational institutions and area industries have always proven to be beneficial partnerships. These joint ventures are not new for The University of Toledo. Area industries have played a long-standing role in the successful educational process for students. The Senior Design Clinic is a joint collaboration among the Mechanical Engineering Department Senior Design students, faculty and industries. As participants in the clinic, students work in teams using knowledge gained in earlier courses to solve real world design, manufacturing and operational problems relevant to industries. Oral and written communications with participating companies as well as teamwork are stressed. Other topics include design for manufacturing, patents, product liability, safety, ethics, technical report writing, and presentation skills. Industries play a major role in the success of this program by providing an engineering project challenge and technical as well as financial support. As members of the clinic, the industries seek and obtain a solution to a specific engineering project or problem relevant to their organization within a short time. Secure laboratory space is provided for the students and clients that is equipped with computers, fax, phone, hand tools, and dedicated workspace.

The primary purpose of the senior design clinic was to form a partnership between academic and industry and enhance their senior design capstone course experience. Students would take the skills they garnered through their three or more mandatory cooperative education experiences and use them to perform as a consulting team during the senior design clinic experience. The clinic was the administrative and financial side of the academic experience. Course work was delivered by a faculty member whereas the consulting activities were administered by the clinic

director. Students would graduate with over a year of experience working with industry through co-op and the senior design capstone experience. Several of the students at the completion of the project would garner full time employment through the company they had interacted with during senior design. Additionally, students were given parameters in regards to leadership roles, budgetary preparation, peer evaluation, travel expenses and reporting and accountability to their team. All of these expectations prepared the students to enter the work force full time upon graduation.

### ***Industry Sponsored Project Example - Emdeon***

This project was completed in the spring of 2010. The objective of this project was to design, analyze, build, and test a device that would stack empty letter trays from a conveyer belt to a pallet layout of three by four and ten trays tall. This was designed for a Toledo-based company, Emdeon, which was taking steps to reduce corrugated cardboard use by replacing containers with reusable plastic trays. One major issue was that the final design of a letter tray that incorporates injection molding design, grip point features, and an acceptable stack up tolerance. The design project focused on the end effector for the tray palletizer as well as coordinating the installation and layout of a robotic arm for the conveyer system through a systems integrator. This operation was to be reliable and used five days a week for twenty hours a day with minimum down time. By using automation a worker would be able to focus less on repetitive tasks and more on quality and organization.

### ***Industry Sponsored Project Example - Rieter***

This project was completed in spring 2007. Several problems existed with the method Rieter previously used to apply a mold release solution which affected safety, quality, waste, and cost. The previous system spray system produced a large amount of overspray; this overspray caused irritation to nearby press operators and covered periphery equipment, causing cotton fibers to stick and create a fire hazard. Eliminating or at least controlling these safety hazards was the top priority for the new design.

Another issue with overspray was excessive waste and cost. A significant amount of Mold Release solution was going to waste when uncontained spray missed the target tool surface area. Improving the design of the spray geometry was very important in addressing this issue. Also, all of the presses are currently equipped with spray wands, which the operators manually control, to apply additional Mold

Release as needed. Eliminating the use of these manual spray wands was a key design goal for the team in the effort to improve process control and decrease the total amount of mold release used.

Inadequate and inconsistent coverage of the Mold Release solution on the Mold Press surfaces resulted in damage to the finished parts when they stuck to the tool. This created quality issues and caused parts to be scrapped. Also, nozzles and tool surfaces needed to be cleaned frequently, resulting in lost production and increased down time. Creating a way for the nozzles to be cleaned quickly and/or preventing the nozzles from clogging in the first place were key ends to improving the tool coverage and reducing scrap. Better containment of the Mold Release spray would further reduce the frequency of cleaning.

The team designed a working prototype system to address the problems identified. In order of priority, here were the objectives: eliminate safety issues; prevent nozzles from clogging (if using a similar spray system); Improve process consistency and system reliability; increase productivity; reduce maintenance (cleaning); and keep material cost low and decrease amount of Mold Release used.

The finished product needed to be very consistent and reliable. The team obtained materials and some donations to make this a low cost solution. The final design is easily adjustable and widely adaptable, so that Rieter can implement it on other Mold Press machines. It also was designed with many removable and interchangeable parts for easy cleaning. The modified design was completed at a cost of \$1,960 which was provided by Rieter Automotive.

### ***Interaction with Industry and Problem Resolution***

Projects were solicited by the director of the clinic who was the industry and alumni contact for the department. Projects were solicited by tapping into the alumni base and department industrial advisory board of the department. Department had a consistent record of inviting and visiting industry prior to the creation of the senior design clinic. Natural partnerships with these individuals and companies allowed the director to solicit 29 projects prior to the fall semester. With the abundance of projects available department students were given the opportunity to give first, second and third choices which created enthusiastic teams on each of the projects. Projects not picked up for fall semester were carried over to the spring semester once industry gave their consent and were reoffered to spring semester students. Some of the projects required a team of students in addition to mechanical and industrial engineering students. Should an industry partner request

an interdisciplinary team the department of discipline was contacted and students were given the option of joining the team and given course credit through their home department. Protection of proprietary information was a concern, however forms were signed by all interested parties which protected the company from liability and their proprietary information and gave patent rights in name only to the students and faculty member participating. All monetary rights were the sole ownership of the industrial partner.

### ***Technology Transfer and Intellectual Property***

Considering that the end result of the project is a technological project, students have a tremendous opportunity to learn about technology transfer and intellectual property. The Design Clinic integrates this into the course by dedicating one lecture period to the related issues. A Patent Lawyer from the University's Technology Transfer Department provides a presentation and question/answer session that covers patents, trademarks, commercialization, and entrepreneurship. The Patent Lawyer also discusses the University's role in technology transfer, the evaluation of potential ideas using a standardized process, financial support inside and outside of the University, and legal aspects associated with working with an outside client on a new design.

### ***Assessment of Outcome Achievements***

An achievement of course outcomes is tested through instructor evaluation and student questionnaires followed by faculty focus group assessment. For a course to be considered assessed, the instructor, students and focus group must have tested and evaluated achievement of at least 75% of the course outcomes. Because of the variation in grading schemes by different faculty, the acceptable achievement level in each course outcome is set by each instructor, and the level is reviewed and discussed when the focus groups performs the actual assessment. To assess their perception of the level of course outcome achievement, students rate their achievement of the course outcomes based on a scale: 1 = excellent, 2 = high level, 3 = adequate level, 4 = below adequate, 5 = none or not covered. The acceptable level for the achievement of course outcomes is 3. Based on data from the student questionnaires and instructor's evaluation, each course outcome is rated as achieved, not achieved or not assessed by the focus group assigned to assess the course. The metric goal is 1 for achieved, 0 for not achieved and NA for not assessed. Since 1997, over 90% of all outcomes have been achieved each semester.

### ***Results and Future Directions***

The overview of this course and design clinic provided in this paper demonstrates that through a cooperative effort and a creative alliance, businesses, universities, and industries can work together to create a strong design experience for engineering students. Over 90 projects were conducted since 1993. In addition, this paper provides a framework for other institutions to duplicate the concepts and processes and adopt similar programs. The program also educates college students through practical, real-world environmental work experience and trains them to become future leaders. The projects promoted increased involvement of UT with the area community, contributing to an increase in media coverage, on and off campus. These projects also increased collaboration between UT and various institutions in the area. In addition, several students in the course have been offered fulltime engineering positions at the companies where they complete their capstone projects.

Future directions for the clinic involve the incorporation of cross functional teams that span multiple engineering disciplines. Several pilot projects were conducted in the fall spring 2011 and fall 2011 semesters that included student teams from mechanical and electrical engineering. These projects typically incorporated moving parts, motors, and programmable logic controllers. For these project teams, both a mechanical engineering and electrical engineering faculty member will be assigned.

### ***References***

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