

# Effective Implementation of Industry Sponsored Senior Design at Stevens Institute of Technology

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## Abstract:

The success of the industry-sponsored Civil Engineering senior design program at Stevens Institute of Technology and its impact on meeting the learning objectives established for the two-semester capstone design sequence is described. The effective use of industry sponsors to formally assess the student's performance will be presented as will the recruitment of sponsors. The dynamics of group size and structure will also be discussed. The information presented in this paper is based on the five years that the program has existed at Stevens.

Initially established to meet ABET 2000 criteria and introduce Civil Engineering students to real world design problems, the industry-sponsored program began during the 2000-01 academic year with two industry consultants (both Stevens Alumni), and 18 students. This program has grown to involve eight industry sponsors and 40 students. The diversity of these projects parallels the Civil Engineering profession and provides the students with first hand exposure of real industry projects, practices and regulations.

Additional benefits of this program include the continual interaction between students and practitioners. Schedules are established and must be adhered to, technical writing and oral communication skills are honed while the students become responsible to an outside consultant. This relationship in many cases has facilitated job placement for the graduates of the program.

## Introduction:

With the implementation of ABET 2000 several changes had to be made within the engineering curriculum at Stevens Institute of Technology. One of the major changes included revising the capstone design to accomplish some of the goals set forth in ABET Criteria *a* through *k* and meet the outcomes established by the Civil Engineering program. In order to successfully accomplish these outcomes and provide each Senior Civil Engineering graduate with a comprehensive design experience, external industry sponsors were recruited to work with the students. The first industry sponsors were members of the Civil Engineering Visiting Committee (CEVC). These Professional Engineers thought the opportunity to mentor and work with the Stevens graduates would be a worthwhile undertaking for both the sponsors and the students.

The industry sponsor, typically an engineering consulting firm, chooses the design project for the students to work on and assigns an engineer from the firm to serve as the consultant to the design team. In addition to the industry consultant, each design team has a designated faculty advisor assigned to the team based on the area of expertise and the parameters of the project, structural, geotechnical, water resources or construction management. Teams also meet regularly with the Senior Design Coordinator to discuss the design progress and the preparation of the report and presentation.

Sponsorship provides funding which goes into a Civil Engineering Senior Design account. The funds are used to build up resources and support activities necessary for the successful completion of the projects. The fund is controlled by the Senior Design Coordinator and has been used to set up a Senior Design Resource Center, purchase computers, printers, plotters and software packages. The funds are also used to support student activities within professional organizations, attend conferences and enter competitions.

During the 2000 to 2001 academic year the implementation of Sponsored Civil Engineering Senior Design Projects began with 18 students and two sponsors. The program has successfully grown with each academic year. The sponsor's enthusiasm and continued support has been enormous. The current academic year, 2004 – 2005, 40 senior design students are working with 8 industry sponsors, one multidisciplinary project in collaboration with the USS Intrepid Museum in New York City and a design project along the waterfront at Stevens Institute of Technology. A summary of the yearly growth of Civil Engineering students and sponsored projects is provided in the table below:

<b>Academic Year</b>	<b>Number of Students</b>	<b>Sponsored Projects</b>
<b>2000 – 01</b>	18	2
<b>2001 – 02</b>	20	4
<b>2002 – 03</b>	21	5
<b>2003 – 04</b>	22	6
<b>2004 – 05</b>	40	7

The sponsored Civil Engineering design program provides the seniors with real life projects and work experience. The student's benefit from the exposure to real world design experiences and learn from experienced professionals the many components which go into a comprehensive civil engineering design. The students are also exposed to the many different types of Civil Engineering designs. Examples of the diversity of the projects include:

- Structural
- Roadway
- Construction methods (innovative design and build techniques)
- Water resources planning and management
- Flood plain management
- Design of treatment facilities

## Waterfront design Historical rehabilitation

These real world projects help introduce the design team to the numerous codes, standards and regulations necessary to consider when completing any civil engineering design. The design teams use all the information to develop design drawings, technical specifications, a cost estimate and a project management schedule. Student teams gain experience using different design software packages. The experience of completing a design, adhering to the many different codes relevant to a particular project, gaining first hand experience with the regulations and the appropriate software tools has proven to be invaluable to our graduates. With the variety of projects presently being sponsored, the students are also gaining a familiarity with the different regulatory agencies they will be accountable to upon graduation.

### **Recruitment of Sponsors:**

Initially discussed and supported by the Civil Engineering Visiting Committee, the first two sponsors, members of the advisory committee, were familiar with the capstone design requirements of ABET 2000. These two companies, Schiavone Construction and LGA, began by providing the students with very exciting real world projects and exposing them to the many outside factors essential to any design.

Upon successful implementation of the sponsored design program and the increased enrollment within Civil Engineering, additional sponsors were needed. The first logical place to recruit sponsors was from the Stevens Alumni Association. A mailing was sent out to all Civil Engineering graduates within the past 10 years detailing the program, its objectives and the required outcomes. The response was slow but steady. The main problem seemed to be the timing of the project's start-up and completion. With the academic year running from late August to the following May, many Civil Engineering firms had trouble pinpointing a project for the students to work on during this time period. Three companies however found the opportunity to mentor and work with senior Civil Engineering students lucrative and immediately began selecting projects that would interest and educate at the same time.

The next group of companies that were contacted where selected from the Cooperative Education Program at Stevens. These companies were already familiar with Stevens and had established a relationship with many of our students.

The recruitment of sponsors continues within these two groups but now also includes Civil Engineering companies that come to Stevens to recruit graduates. We have also been actively soliciting sponsors from local engineering societies such as:

New York and New Jersey Society of Profession Engineers  
Consulting Engineers Council of New Jersey

There have even been opportunities for students to work on designs with local organizations. During the 2000– 2001 academic year, Stevens was approached by the Korean War Veterans

Association of Hudson County to help them design and construct a memorial in Jersey City, New Jersey. Two of the Civil Engineering students worked with the veterans, stone workers and the Civil Engineering faculty to design the monument (Figure 1), generate construction drawings and set up construction guidelines for building the memorial. The memorial was dedicated on April 12, 2001, and bears the names of the student designers. This particular design involved many different components including:

- Foundation for the memorial
- Connection joints for the granite slabs
- Location of necessary utilities



**Figure 1:** Hudson County Korean War Memorial

The students were also responsible for presenting the design to the Jersey City Planning Board and experienced first hand this essential aspect of civil engineering, which cannot be taught in the classroom.

### **Impact on Meeting the Civil Engineering Program Objectives:**

The expected accomplishments of the graduates of the Civil Engineering Program at Stevens Institute of Technology are as follows:

1. Have established a distinctive record of professional achievements within the profession and will have become a licensed Professional Engineer.
2. Be thoroughly aware and knowledgeable in dealing with environmental, social, ethical and economic impacts of their projects.
3. Have augmented their knowledge through Professional and Cultural Continuing Education.
4. Be active in leadership roles within their professional and technical societies.
5. Be innovative and creative in conceiving, designing and construction of a broad range of projects.
6. Continue to demonstrate an entrepreneurial spirit in all their activities.
7. Actively support and advance the educational program at Stevens Institute of Technology.

The implementation of sponsored Senior Design Projects has successfully provided the students with many of the prerequisite attributes necessary to achieve most of these objectives.

*Objective 1: All Civil Engineering graduates will establish a distinctive record of professional achievements within the profession and will have become licensed Professional Engineers.* Working closely with the sponsors has also further emphasized the importance of Professional licensure, a two part series of exams that usually begins during the spring of the senior year. One of the requirements of the Civil Engineering Senior Design is that each graduating senior take the Fundamental of Engineering Exam (FE) during their Senior Year. The funding that is obtained from the sponsors allows the Civil Engineering Program to pay for each student's application. Passing the FE exam is not a requirement for graduation. The FE requirement was enthusiastically supported by the Civil Engineering Visiting Committee (CEVC) who unanimously felt the students should be required to take the FE exam (directly linked to ABET criteria f).

*Objective 2: Be thoroughly aware and knowledgeable in dealing with environmental, social, ethical and economic impacts of their projects.* All students within the Civil Engineering program are required to analyze the impacts of their Senior Design project with respect to economics, the environment, sustainability and manufacturability of the design, ethical considerations, health and safety, along with social and political impacts. These are only part of the design itself but are essential components to the completion and lifespan of any design project. In addition to these considerations, students must also meet all federal, state and local regulations, which pertain to the design (directly linked to ABET criteria f and h).

*Objective 3: Have augmented their knowledge through Professional and Cultural Continuing Education.* Seniors are encouraged to attend workshops relevant to their projects and local conferences sponsored by Professional Organizations such as the ASCE, AWWA, NSPE and WEF. Funding is available through the Senior Design budget. Stevens also offers an on campus FE review for all students, emphasizing the importance of further education.

*Objective 4: Civil Engineering graduates take active leadership roles within their professional and technical societies.* The funding made available to the Civil Engineering students through the sponsored Senior Design Program encourages students to enter competitions sponsored by the ASCE and AWWA. One group of seniors during the 2002 to 2003 academic year presented their design project at the New Jersey American Water Works Association Conference in Atlantic City, New Jersey (March 2003) and received first place in the student design competition. The sponsor of this particular project, Hatch Mott MacDonald, encouraged and supported their efforts (directly linked to ABET criteria d).

*Objective 5: Civil Engineering graduates must be innovative and creative in conceiving, designing and construction of a broad range of projects.* During the Senior Design, some Civil Engineering students are introduced to a project that the engineering sponsor would like analyzed in a new and innovative way. Many of these projects are being worked on simultaneously by the consultant, but with restrictions (financial or social). Students have been asked to push the limits and determine another design alternative. They are encouraged to do research to find out what design/construction techniques are being used outside of the

United States and how they may be implemented within the project. The knowledge that the students gain helps them to take a more innovative approach to problem solving and to think globally (directly linked to ABET criteria c and k).

Two recent examples of projects in which the sponsor encouraged the students to be innovative include:

1. The Macombs Dam Bridge (Figure 2) retrofitting which required the students to analyze this historic structure over the Harlem River. They modeled the entire structure using SAP2000, designed the retrofitting to provide added strength, created redundancy in members to increase safety and developed a construction plan which maintains vehicular, pedestrian and marine traffic at all times. This historic structure, build between 1892 and 1895, is a pin-connected through-truss swing span bridge, which is the most walked over crossing of the Harlem River, connecting the boroughs of Manhattan and the Bronx, close to Yankee Stadium. The bridge is used extensively by fans attending NY Yankee baseball games. In addition to completing an extensive design for the retrofitting the team proposed the use of a Ferry to transport pedestrians across the Harlem River while maintaining two lanes of traffic at all times. This option was met very favorably by the team sponsor, a construction-engineering consultant, who where also dealing with the extraordinary requirements for the construction and the Yankee schedule.



**Figure 2:** Macombs Dam Bridge

2. The replacement of the Victory Bridge over the Raritan River in New Jersey was examined by a Senior Design Team whose main task was to utilize a gantry crane to construct the new bridge from both sides. The construction method and the design of the crane itself was an innovative technique and one that was being worked on by the consultant at the same time. The Victory Bridge has since been replaced and some of the design/construction ideas conceived by the student design team were implemented by the consultant.

*Objective 7: Actively support and advance the educational program at Stevens Institute of Technology.* The accomplishment of this objective is best illustrated by the increased number of Civil Engineering Sponsors who are Alumni of Stevens. The two initial industry sponsors within the Civil Engineering Program were both Alumni of Stevens. Since the implementation of the sponsored senior design program, several other alumni have become active sponsors. Most of these sponsors are made aware of the program through our graduates when they enter the work force. There is a current sponsor, a graduate of 2002, in his 3<sup>rd</sup> year as an industry sponsor for the Civil Engineering Program.

### **Effective Use of Industry Sponsors in Assessment:**

The two primary methods used to assess the Civil Engineering Program Objectives are the alumni survey and the employer survey. Both these surveys evaluate the graduate's achievement and provide feedback essential as to how the Stevens Civil Engineering graduates are meeting the objectives of the program and meeting ABET criteria f, g and h.

Two other assessment techniques recently implemented by the Civil Engineering Program at Stevens and directly linked to the Senior Design requirements are:

1. The FE results, which have recently been provided by the New Jersey Board of Professional Engineers and Land Surveyors.
2. The Senior Design Evaluation Form, which is completed by the industry sponsors and faculty advisors for each design project in December and May. (The most recent evaluation form appears on the next page).

The requirement that each senior take the FE exam during the senior year enables the Civil Engineering program to use the FE results as an assessment tool since 100% of the students take the exam. The FE results, provided by the Board of Professional Engineers and Land Surveyors, give a detailed breakdown of scores, pass or fail, within each of the subject areas tested on the FE exam. This data is used to assess the students overall engineering knowledge and evaluate the engineering curriculum at Stevens.

Up until this time the FE results could not be used to assess the students undergraduate preparedness while still students at Stevens. This was due to the fact that the New Jersey Board of Professional Engineers and Land Surveyors would only allow senior engineering students to sit for the FE exam in April of their senior year. The results of the exam are provided to Stevens four months later, in August, when the students have already graduated. A recent meeting with the NJ Board has resulted in a major change in that senior engineering students will be able to sit for the FE exam in October of their senior year. Thus the results will be made available in February. This will allow the Civil Engineering program to use the results to assess the student's performance in the undergraduate program and identify the strengths and weaknesses of the engineering curriculum.

The Civil Engineering Senior Design Evaluation Form provides feedback that is critical during the December submission of the design project and leads to improvement for the final submission in May. The form provides assessment information on criteria beyond the engineering design. The information is used to improve team communication, organization and group management skills. The evaluation form also provides incentive for the students to give a thorough, intelligent and innovative oral presentation and submit a design report that is well written, professionally presented and accurate.



# Civil Engineering Senior Design Evaluation Form

Group or Project Name \_\_\_\_\_

Evaluators Name \_\_\_\_\_

***PLEASE COMPLETE THE FOLLOWING USING A SCALE OF 0 TO 4 WITH 4 BEING THE BEST AND 0 THE LOWEST POSSIBLE SCORE (use back of sheet if necessary)***

## **Oral Presentation:**

Visual aids quality \_\_\_\_\_

Technical content \_\_\_\_\_

Clarity \_\_\_\_\_

Time management \_\_\_\_\_

Group participation \_\_\_\_\_

Overall presentation comments \_\_\_\_\_

## **Written Report:**

Organization \_\_\_\_\_

Description of project \_\_\_\_\_

Technical content \_\_\_\_\_

Clarity of work presented \_\_\_\_\_

Accuracy of calculations & methodology \_\_\_\_\_

Results and conclusions \_\_\_\_\_

Overall comments on the report \_\_\_\_\_

**As part of the ABET Criteria all reports and design projects must include the following design standards and realistic constraints. Please evaluate the project for each of these considerations using the same 0 – 4 scale. If the constraint is not applicable to the project, please label it NA.**

Economic considerations \_\_\_\_\_

Environmental considerations \_\_\_\_\_

Sustainability of the design \_\_\_\_\_

Manufacturability \_\_\_\_\_

Ethical considerations \_\_\_\_\_

Health and safety \_\_\_\_\_

Social considerations \_\_\_\_\_

Political \_\_\_\_\_

**Recommended Grade for the Project** \_\_\_\_\_

### **Dynamics of group size:**

Enrollment has increased within the Civil Engineering Program at Stevens in the past 5 years. The senior class has grown from 18 to 40 seniors since 2000. These students have worked extensively in teams throughout the rigorous engineering core design lab sequence, which culminates in the senior design. As seniors, most students will know which particular area of Civil Engineering interests them and what type of project they would like to work on. Typically the recruitment of sponsors for the academic year takes place between March and April. Once the sponsors make the commitment to Stevens, a list of sponsors and “typical projects” is generated and presented to the junior class in mid April. Teams typically consist of 3 to 5 students who select projects based on their interest or the consultants they are interested in working with.

Once the teams have been formed a “kick off meeting” is set before the end of the junior year. This meeting allows the students to meet the consultant, collect the necessary references during the summer break and also visit the site in mid August prior to the beginning of the academic term.

Group members must stay together throughout the course of the project (two semesters). Leadership roles will vary during the design process. Typically there will be a team leader, a liaison between the group and the sponsor, a design scheduler who keeps track of the design progress and design engineers. These roles ideally rotate throughout the course of the design.

Some conclusions that have been observed during the 5 years of sponsored Senior Design at Stevens are that the optimum group size is 4 with one of those members being proficient in the use of AutoCAD, the drawing standard used by most of the consultants. Teams of less than four tend to be overwhelmed by the many components they are responsible to consider during the design process. Teams with more than 4 tend to have members who do not contribute sufficiently and the team tends to overwhelm the consultant. These conclusions are not based on any scientific data, but are the results of 5 years of evaluations and feedback from the industry sponsors and the students.

### **Conclusion:**

The implementation of Industry Sponsored Senior Design at Stevens Institute of Technology has proven to be a tremendous success. Students are excited about the opportunity to work with industry sponsors and gain real life knowledge of Civil Engineering design. The external factors that must be considered with each design are site specific and something that is very difficult to teach in the classroom. Students are also able to improve their communication skills through the continued contact with the sponsor and the two oral presentations required for each project. Teamwork is a necessity since the students are responsible to the Senior Design Coordinator, the Faculty Advisor and the Industry Sponsor. Students experience first hand the complexities of scheduling, and meeting the dates established for the proposed design.

The feedback from the alumni has been very positive. They enjoyed the opportunity to work on “real life” projects, visit an actual site and address issues such as permitting, codes and standards. These are all aspects of design they will need to consider when they begin their careers as Civil Engineers.

The sponsors continued support of the program has been enormous. Each industry consultant has returned to sponsor another design project for the following academic year. Their continued mentoring of our graduates has been invaluable. The sponsors feel that the time and money is well spent educating the engineers of the future, some of whom become their employees.

Finally, the implementation of the sponsored Senior Design project within the Civil Engineering program at Stevens was received enthusiastically by the ABET evaluator during the accreditation visit of November 2003. The extensive scope of the projects and the level of the design meshed very well with the ABET criteria requiring students to look beyond the design and account for many external factors impacted by the project.

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