

# Civil and Environmental Engineering Capstone Development in Partnership with Industry at NJIT

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The Senior Capstone course at NJIT was declared an experimental zone starting in Fall, 2010. Until that time, there had been little recent connectivity between NJIT's Department of Civil and Environmental Engineering and practicing engineers and their employers in developing a culture of volunteering and contributions to the curriculum. Such connectivity was started in Fall, 2010 and each semester the connections have grown stronger, more varied, and more successful. Students appreciate this course, and they are active participants in the continuous improvement of the course as a real-time experiment. Thus far, the class has been limited to six 4-student teams. Scaling this up to handle more than 100 students will be a challenge in organization, administration, and mobilization of mentor resources.

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## ***Introduction***

The New Jersey Institute of Technology was founded originally as the Newark Technical School in 1881 as an industry-grant (similar to a land-grant) institution serving the growing industries of northern New Jersey. The campus is Newark, surrounded by urban and suburban communities of high population density. At any given time, there are many public and private projects underway in the area, extending from suburban residential site development to intensely urban and commercial projects.

The Department of Civil and Environmental Engineering (CEE) was one of the first departments established in what became the Newark College of Engineering (NCE) in the 1930's. NCE was strongly connected with industry in the area, and many of its faculty members were active in practice as a direct employee or in consulting. In the 1970's, NCE was joined with the New Jersey School of Architecture to form NJIT, which was identified as one of the three research institutions of higher education in New Jersey. From then to the present, the strategic plan for NJIT became increasingly focused on research, leading to its current stature as a Research-I, high research activity institution.

With the recent trend of decreasing state support CEE has worked to increase engagement of alumni and industry in the activities of the institution. Discussion in the CEE department has led to an invigorated Industry Advisory Board (IAB), which has been primarily engaged in general curriculum considerations, accreditation, and participation in the first year fundamentals of engineering course to introduce students to civil and environmental engineering as a career. Enhanced engagement of industry in the context of a redesign of the senior capstone design

course (CE 495) was strongly supported by the IAB, and during the short time that the new course has been in place and evolving, industry interest in hiring its graduates has increased. From a survey of students, more than 50% of those completing this course in Fall 2011 received job offers reportedly and specifically because of the work they had completed in CE 495.

With a commitment made to develop the capstone course in collaboration with industry, the course development plan had to acknowledge that NJIT is an urban school with a majority of its students not in residence on campus, and with many working part or full-time while attending school. Finding time for student design team activities and meeting with practitioner mentors was expected to be a challenge in developing an engaged capstone experience.

In developing required contacts with north Jersey/New York City area firms, CEE found many firms hesitant to release information about past, present or future projects because of liability issues and legal concerns, high competition, and the reliance by firms on their past record and information resources as being the competitive edge for them in getting future jobs. Public works civil projects could potentially be a source of project material, but there was no strong connection between cities or counties in the area and using public projects in courses. The organization of information within the agencies was also not conducive to preparing projects for students to work on for design.

## ***First semester (Fall, 2010)***

The purpose of the CE 495 (Civil Engineering Design II) course, required of all seniors, is to provide a realistic experience by integrating basic material learned during the engineering undergraduate program to address real-life design problems from the feasibility into design

levels, including advanced engineering design aspects in certain selected focus areas of technical discipline. This course is meant to follow the CE 494 (Design I – focusing on site development) course, but in fact many students were enrolling in the two courses at the same time, so that student time was stretched thin by having two major design projects due at the end of their final semester.

In August 2010, personal and professional society and alumni connections were used to identify potential capstone mentors and projects from engineering practice. Prospects were invited to contribute to the CE 495 course by preparing projects or contributing their time and knowledge in the classroom to enhance the learning experience for students. The course was divided into three parts: A – Feasibility Design for a Project; B – Modules on Business, Ethics and Leadership; C – Advanced Design for a Project. The first course part also included discussion of specific code, performance, cost, time, quality and safety objectives, and lectures and class exercises focused on the process of design.

To identify projects for parts A and C, the instructor connected with city and county engineers. One county engineer agreed to develop an initial feasibility project for the first four weeks of the course involved with construction planning for a major road rerouting in the NYC area. Student teams all worked on the same project, and completed a report and a presentation on their conclusions at the one-third point in the course. A trial rubric was established for student peers and practitioner evaluation of the presentations.

By the time the feasibility project was concluded, the instructor had been able to identify sufficient projects from industry so that the advanced design phase of the course could begin. Four-student teams were formed, each with their own project including foci on transportation, structural, and environmental engineering. Engineers and managers from practice acted as “Practitioner-Mentors” (or PMs), meeting with the teams, helping the students to realize when “just-in-time learning” was warranted as they encountered issues not included in their coursework thus far, arranging field visits where possible, coaching the students on report writing and presentation preparation and, in general, acting as clients for the student teams in their approach to design. In all cases for this first semester, the PMs acted as individuals and not as a team from the firm or agency. This meant that the PMs had a major individual time commitment that was difficult to juggle and keep their day job commitments satisfied.

This first trial with design projects worked well, but there was room for improvement. Project scopes varied widely and it was realized that more focus on upfront expansion or de-scoping would create better

projects for the students. In addition, most projects were not broadly multidisciplinary, and it was important for the instructor and the PM to work throughout the semester in tweaking the project to keep the student work load reasonable while making sure that the project stayed open-ended and engaged broader content than as originally posed in a relatively narrow disciplinary silo.

Meanwhile, other industry volunteers were involved in the course through preparation of lectures or participation in discussions/panels on important aspects of professional practice. Multi-lecture modules were developed in the topic areas of ethics, leadership, and engineering business practice. Focused lectures were also developed that brought ideas on regulations and permits, green engineering, and globalization into the classroom.

### *Second Semester (Spring, 2011)*

In preparing for the second offering of the experimental version of CE 495 at NJIT, CEE considered several modifications incorporating many aspects of course development at Purdue.<sup>1</sup> Additional connectivity had been established with regional practice so that more options became available for course development. The instructor worked with potential PMs to identify projects, and to work with the firm or agency to develop a team involvement of practicing engineers in mentoring – something that would lighten the load on any individual and make it more likely that PMs and student teams could find common times to meet for project discussion and consultation. The PM firms have found more enjoyment in having an engaged team of mentors, and this has actually worked out to be a valued way to train the younger staff in leadership, allowing them to contribute to the mentorship the NJIT student teams.

Each project also was framed differently. Following discussions with the first semester PMs, CEE decided to organize projects so that the first project phase was actually for the students to prepare a proposal responsive to an RFP (Request for Proposals) prepared by the PMs. The student teams used the first four weeks of the semester to prepare their proposals, and then a major event was scheduled at which each of the teams presented their proposals and answered questions following their presentations. This allowed there to be some time for the PMs to think more thoroughly about their project, and come to a better understanding of the level of student preparation and understanding of the project very early in the design experience. It also allowed the students more time (the whole semester) to focus on all aspects of their project, and this resulted in improved treatment of the technical content issues in design.

During the Spring 2011 semester, the students were assigned to teams not only based on their interest and alignment with the technical content of the different projects offered, but students also completed a Myers-

Briggs Type assessment of personal psychological preferences, obtaining a MBTI (Myers-Briggs Type Indicator) index. These indices were used to help assign students to groups, and several in-class exercises were developed for students to understand more about how to work well in teams to succeed in their goals and to achieve in their personal satisfaction regarding the project. The students appreciated learning about team dynamics and how they personally could be more aware and understanding of how teams work best.

This semester, NJIT also began to offer PDH (Professional Development Hour) credits for participation in CE 495 as lecturers or PMs. In addition, NJIT partnered with Engineering Better Readers (EBR, through ASFE's Engineering Leadership Fdn. <http://www.engineersleadership.org>) and a local K-4 elementary school to involve the NJIT student teams in writing a kids book about some aspect of their project, design, and/or teaming. This books will be placed on an electronic bookshelf that may be accessed by kids and their teachers and parents.

### *Third Semester (Fall, 2011)*

In the third semester, CEE was able to recruit one industry volunteer to participate in a new mentoring role - he became the course coach for constructability evaluation, making himself available to any student team in discussing their design and problem solutions.

The lecture modules on specific topics have continued to evolve. During this semester, a four-lecture sequence was added on risk assessment and management, and treatment of risks was explicitly incorporated into the design projects as a formal part of design. The ethics and leadership lectures were redesigned to include speakers from the legal profession, public agencies, contractors and consulting engineering firms. Panel discussions among the presenters added greatly to the enjoyment of both the students and presenters in the activity. Sequences of lectures were also added that discussed green engineering and sustainable design, and the business of engineering, including perspectives from small and large firms, individual consultants, and firms working in regional, national and global arenas. The role of engineers in marketing was also included.

Students were individually required to provide written feedback/evaluation for all lectures presented by industry practitioners. The rubric in use was derived from one prepared for an existing seminar course, modified considering the experience found in other capstone programs.<sup>2</sup> In fact, the sequence of lectures proved very popular so that students (including graduate students) and some faculty attended the lectures as well. Increasing numbers of people from practice have been attending, and NJIT is working to

establish PDH credits for those lectures with content that warrants such credentialing. This is yet another way that the capstone course has worked into a win-win-win situation for students, university, and industry.

The team assignment of writing a project-linked kids book was continued, and a children's book author lectured on writing and illustrating for children. This improved the book quality, and the books were introduced to teachers and students in the Newark Public Schools.

### *Planned 2012 Semester Activities*

In 2012, NJIT plans to continue to develop the PDH system for industry involvement. Individual lecturers will pose essay questions related to their presentations, and student submissions will be graded by the lecturer for content. We will partner with the Humanities Department to provide feedback to students on their writing abilities.

NJIT's CEE department has also started to engage the Department of Water and Sewer Utilities of the City of Newark in identifying problems to be solved in research and development efforts, projects for design, as well as co-op, internship and research positions and projects that will engage students and offer new opportunities.

In addition, CEE will expand on the event held at the end of the semester at which projects are presented and discussed. Thus far, this event has been for the class only, but CEE will expand the event as a showcase of capstone projects, and will invite industry and practitioners to attend and learn what student teams can do in a design environment. CEE will revamp its web site to include special focus on the senior capstone course and the industry and practitioner contributions and participation. Generating publicity and press releases about our activities will support continued growth of the effort.

The Engineering Better Readers project will be expanded to build an electronic bookshelf of NJIT-written kids books, and also to build a reference resource for parents and teachers on books with recommended engineering content for kids, written in any language. The web site for this creativity resource will be launched in 2012. CEE will continue its partnership with Newark Public Schools, and a formal approach to assessment is under development.

### *For the Future*

For the future, CEE will continue to expand industry connections, and to work closely with the engineering divisions in the City of Newark and other north Jersey cities to develop connections, projects and opportunities for students in urban planning and development. The best success in recruiting PMs has come from:

- Networking and following-up with contacts from local and regional professional society meetings.

- Inviting practitioners to present seminars and then expand their involvement into project mentoring.
- Connecting with alumni, and making presentations on the CEE program at alumni clubs formed in many regional engineering firms.

CEE has also learned several lessons about developing industry participation in the capstone experience:

- a) It is important to spend significant time with the PMs in developing the RFPs, including developing the reference materials students will need to complete their projects, and to avoid confusing students when they receive different project guidance from the faculty and from the PMs.
- b) Involving practitioners as presenters in PDH – bearing lecture modules has significantly increased their interest level in course participation.
- c) While student teams have been successful in their projects, the road has not always been without bumps. It is important to have student team leaders provide a summary of weekly team activities and interactions with their PMs so that problems can be identified and addressed early.
- d) It is important to spur motivation through web-articles and news releases to publicly acknowledge participation of PMs and firms in the projects.
- e) It is important to provide e-resources<sup>3</sup> for students and PMs to post information and project Q/A communications. NJIT uses Moodle for course learning materials, but this platform is not embraced by all lecturers and PMs.
- f) It is important to involve PMs in assessment<sup>4</sup> of the course and of the student performance regarding both engineering design content and presentations. CEE plans to develop the Executive Panel concept<sup>5</sup> to support communications assessment, and has collected rubrics from several capstone program developers<sup>6,7</sup> to revise the assessments for 2012.

CEE will also consider looking for problems to be solved rather than projects to be designed in interacting with industry. Design is not only project-based for public or private works in CEE, but can also involve problem solving and innovation in terms of technological applications and development of new means and methods. In order to embark upon this course modification, intellectual property issues will need to be addressed. This approach may well allow focus on designs beyond the typical CEE projects and avoid legal and liability concerns of releasing information that is the subject of some sensitivity for many engineering firms and owners.

The CEE department is considering making the two course 494/495 sequence into a single two-semester course that can be better integrated, involve a more broadly engaging project, and allow a more reasonable pace for sustainable interactions between the PMs and the student teams to develop. The department

is also discussing approaches to develop financial underpinning to support course activities.

A particular challenge for the future will be to scale the course up to involve all undergraduates in their senior year. To this point, the experimental course section has been limited to six 4-student teams, scheduled as an evening course to enhance the possibilities for active engagement by industry, and to service NJIT students that were working full- or part-time while completing their degree. Handling more than 100 students through the course each year will mean both day and evening classes, so that highly active participation of industry PMs may be increasingly difficult to arrange. Only one faculty member and no other staff has been involved in course development for these two experimental years. Scaling up will warrant a commitment to devoted staff

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