A Unique Interdisciplinary Approach Civil & Environmental Engineering Capstone Design Class

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A unique interdisciplinary and collaborative approach to project based learning within the Capstone course is a key aspect of preparing civil engineering students for professional practice at the University of Wisconsin-Madison Department of Civil & Environmental Engineering. The focus of this Senior Level Capstone course is to immerse students in a situation where they work on a real-world design challenge in mentored cross-curricular collaboration with students in other disciplines. Through synergistic projects, students from diverse disciplines work collaboratively from project inception through completion providing positive impacts upon student outcomes and expectations. This includes students from the fields of engineering, architecture, and landscape architecture. The focus of this paper is to delineate and illustrate the unique aspects of this Capstone course.

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Introduction

Instilling an understanding of design and the design process is a key aspect of preparing civil engineering students for professional practice. At the UW-Madison, College of Engineering, Department of Civil & Environmental Engineering, the focus of the Senior Level Capstone course is to provide a unique multi-disciplinary, real-world project based learning experience.

The Capstone course is a 16 week, 4-credit class meeting on Tuesday and Thursday mornings from 7:45 to 9:15 am. Consistent with ABET criterion 3, in particular student outcomes c, d and e, this class prepares students for professional practice though a comprehensive experience involving design, management, economic, social and leadership aspects. This course integrates prior course work and skills, such as Technical Writing and Communication and Building Information Modeling. Other significant contributing design courses are from areas such as Construction Systems, Geotechnical Engineering, Structural Design, Transportation Engineering, and Environmental Engineering.

The scope and depth of the course involves both formal lectures and active practical investigations within a team environment. The Tuesday professional practice lectures provide a broad overview of applicable topics with some in-depth case study. Content, in part, is geared towards the informational needs of student teams in completing upcoming assignments. The Thursday hands-on group work sessions with mentors bring critical thinking and design skills into focus through the student's integration of prior learning and applying it to a real project.

Before the semester begins, students respond to a questionnaire and provide a brief resume to instructors. Instructors review the information and assign students to teams in one of four areas of focus; General Building, Transportation, Environmental or Geotechnical, based upon their academic coursework and performance, practical experience, and career goals. Each semester the course embraces 10 to 12 different projects, typically involving projects that have been selected in conjunction with our Capstone Partnership.

The students are organized into teams of four to six individuals, typically including three to four different disciplines within Civil Engineering. This small group arrangement, consistent with ABET criteria d, helps to ensure all students are effectively engaged in the learning process throughout the semester. Each student group typically has two industry mentors that work with the group throughout the semester.

Active student involvement is the key to successful engagement of students in this course. 12 of the 17 class assignments are design team related. This ranges from preparing written proposals and summaries to the

development of drawings, specifications and other procurement and contract documents. Class presentations to peers and formal presentations to judges also are important group activities. The class fosters essential joint learning activities such as role-playing, small group discussion, and collaborative problem-solving.

Mutual responsibility for the overall team effort and work product is cultivated within the group setting. Students on each team also assess each other's performance four times each semester utilizing a Peer Evaluation process submitted to the instructors. Effective teams assume shared responsibility for collaborative work, and value the individual contributions made by each team member.

As part of the real world design project, student teams must present the project to a jury at the preliminary design and final design milestones of the semester. Jurors take on the role of the client's board members. Communication skills are a significant key to these presentations as they are in the 21st century workplace. Students have been exposed to and explored a wide variety of soft skills and graphic communication skills in previous courses. The Capstone course enhances these student skills with multiple class time presentations related to graphics, selling ideas and making effective presentations.

Interdisciplinary & cross-curricular teams

About one half of the Civil Engineering student teams are coupled with student teams (and their mentors) from other disciplines to form a larger working project team of six to ten members. These multi-discipline teams are formed with students from other disciplines within the College of Engineering and from UW-Madison Department of Landscape Architecture, UW-Milwaukee School of Architecture and Urban Planning and Madison College Architectural Technology Program. Students from other programs are typically Independent Study, Thesis or Graduate students.

Instructors maintain a close relationship with faculty and instructors in the other programs frequently comparing observations on progress and collaborative efforts. Instructors begin planning at least six months in advance of the semester to coordinate scope, schedule, and deliverables between colleges and in conjunction with the "client".

The student teams research and design broader aspects of the project, integrating the design of systems and components and relating to the user group/client in a manner closely simulating real world situations. With the help of mentors to orchestrate and encourage, students are brought out of their "silo" or area of expertise to strengthen interplay, participation and communication between disciplines. [1]

In these multi-discipline teams, the role of mentors becomes more critical to successful outcomes. Our empirical data gathered over several years indicates that student team outcomes are heavily dependent upon the quality of mentor interaction with the team. Instructors have traditionally met with mentors before the semester classes begin to discuss projects, curriculum and expectations. As part of the constructive feedback and self-critique, the instructors have been able to better align mentor expertise and course expectations for individual projects.

Collaboration

Collaboration relative to the student team focuses on working together to realize shared goals by sharing knowledge and learning, building consensus and developing leadership within the team. Students must develop the ability to work effectively and respectfully within these diverse teams. Students must learn participation and thinking strategies while collaborating and negotiating with people of related disciplines. The team members learn to be good listeners and to articulate ideas effectively using oral, written and nonverbal communication skills in a variety of forms and contexts. [2]

These teams utilize a variety of electronic platforms in which they create, share and/or exchange information and ideas. The effectiveness of the technologies is still evolving through experimentation. Collaborative file sharing through the Cloud, and with software such as Autodesk REVIT and Prezi, allows multiple users to access files at the same time and from a variety of devices, creating significant efficiencies.

Project based learning

Project-based learning is an effective and comprehensive approach to teaching in which students learn from real life in a multidiscipline and collaborative environment. Students learn knowledge and elements of the core curriculum, but also apply what they know to solve authentic problems, broadening their experience. They learn how to participate in and lead multidisciplinary design teams. They meet the design challenges using an array of skills from basic math and language arts to team dynamics and computer technology. [3]

Utilizing project-based learning strategies in the classroom leads to a greater depth of student

understanding of concepts, broader knowledge base, improved communication and interpersonal/social skills, enhanced leadership skills and increased creativity.

The instructors and mentors guide students in learning and practicing skills in problem solving, communication and team-management throughout the project. Project-based learning encourages the development of problem seeking and problem solving abilities associated with lifelong learning and career success. They learn that team social interaction is an important component of developing a design solution and they gain an understanding of the methodologies, goals and constraints of other disciplines.

Real-world projects

Real-world team-based design projects are at the core of project-based learning. Real-world projects provide an excellent way to involve industry practitioners in education and it provides practical experiences and challenges for the students. Team-based projects provide opportunities for students to learn individually as well as teach others in small learning groups. The team arrangement also introduces the students to the need for effective team leadership, project management and teamwork required in actual professional practice.

The projects are open-ended and not fully defined in advance for students, yet are guided by a Standard Scope of Services, ensuring some degree of conformity between final deliverables. This also ensures documentation of ABET student outcomes attainment. The student team must find their way through the project design process with the guidance of instructors and mentors. With this type of active and engaged learning, students are inspired to obtain a deeper knowledge of the subjects they are studying.

Appropriate "goldilocks" projects fit well with the semester time frame and yet present multiple design challenges for the team, especially related to investigating and presenting options or alternatives to the client. Ideal projects also provide real user-client interaction. For example, the project design may generate multiple alternatives, provide optional selections of materials and develop several phasing alternatives for construction. These kinds of challenges provide the team an opportunity to show a depth of design thought.

Key projects for spring semester 2014 include:

Design of a mid-rise, cross laminated timber residential building at the Milwaukee Inner Harbor (structural, environmental, geological, const. management and architecture).

Redesign of a major intersection (rail, bicycle, pedestrian, motor vehicle) in downtown Madison (transportation, structural, geological, construction management, and environmental).

Restoration of the Upper Pond at Frank Lloyd Wright's Taliesin in Spring Green (environmental, construction management, landscape ecology, cultural resources and landscape architecture).

These three projects involve 24 students from four different educational curriculums, eight mentors from five different professions and faculty from three programs.

These projects have a willing client, clearly defined scope, specific time frame and program. The scope of these projects are consistent with the capabilities of the students and the length of the academic semester, yet broad enough to be consistent with the goals and objectives and desired learning outcomes of the course. These projects provide a significant challenge to the communication and collaboration skills and creativity and innovation of the student teams.

Capstone partnership

The UW-Madison Department of Civil & Environmental Engineering Capstone Partnership is a cooperative arrangement among groups and institutions that develops and fosters strategic partnerships within the engineering industry. [4]

The core purpose of the Partnership is to organize and implement specific joint industry and student projects meeting the design needs of Partnership participants. The Partnership facilitates interactions between UW faculty, researchers and students and industrial partners to address challenges in solving a wide range of design problems for regional businesses, government enterprises and institutions.

The Partnership seeks to increase collaborations with key business, industry, and agency stakeholders in the broad area of civil engineering design, to foster collaborative work between academic and industry participants and to enhance the engineering student experience.

Proposed projects are advanced through a screening process to evaluate the potential to benefit both the industry sponsor and the students. Highly ranked projects have a willing client, funding, clearly defined

scope, specific time frame and program. The scope of these projects is consistent with the capabilities of the students and the length of academic semesters, yet broad enough to be consistent with the goals and objectives of the industry client.

The Partnership also engages the participation of industry mentors for each semester. Planning four to six months in advance, the partnership relies on a very energetic and diverse pool of local engineers, construction managers, architects, researchers and others in the industry to provide 20 to 24 mentors each semester. This group donates in excess of 500 hours of time to the class each semester to help students achieve their potential and expand their abilities within the "real world" experience of the Capstone class.

Refinement

Constant improvement is an important goal of the instructional team. The input for refinements is gathered throughout the semester.

Practitioners and members of the local business community act as judges and participate in the role of the client at the mid semester and final presentations. Judges come from many disciplines and a wide variety of backgrounds attempting to represent a realistic client profile. The same judges participate at mid-semester and final presentations which further develops the "client relationship" for the student groups. Presentation feedback also helps shape the content of the project considerations as the Judges pose questions and provide commentary the student teams. Judges and mentors provide feedback to the instructional team relative to overall class performance.

A series of rubrics are used for assessing and evaluating attainment of ABET Student Outcomes in the capstone course. Judges, mentors and a panel of Professors of Practice formally undertake this assessment and evaluation each semester reviewing actual student deliverables and presentations. The results are presented on an outcome-by-outcome basis, each with an interpretation of the results and recommendations for moving forward. The course consistently meets or exceeds expectations. [5]

End of semester course improvement feedback is multi-faceted. Individual students complete a course evaluation and each student team has a personal interview, or debriefing session, with instructors and mentors. This constructive feedback is timely, honest and information-specific. All of the feedback provides the course instructors with the opportunity to continually improve the effectiveness of the course. This is implemented through gradual refinement of course content and processes leading toward consistent improvement in positive outcomes. The course instructors also develop a self-evaluation of course outcomes based upon detailed observations and notes made during the semester.

Summary

After almost two decades of evolution, this course continues to progress. The instructional team has guided its development with long-term values in mind. The model and organizational structure are near full development but by no means near a perfected condition. The instructors and mentors now focus on providing students, those engineers of the future, with positive experiences and encouraging life-long learning. Students, faculty, mentors, judges and clients consistently report positive experiences.

Preparation and coordination are significant on-going tasks within this non-traditional course that are required on a weekly basis. In addition, the diversity and complexity of the scope and engagement of end-users into the projects has increased the role of the instructor from initial selection of projects through organizing and maintaining the daily momentum and coordination of the course.

The quality of work products produced by the students has incrementally increased in terms of depth and breadth and consistency with norms of actual practice. Feedback from employer surveys indicates the class has made progress in instilling life-long learning qualities including: self-directed and independent learning, participation in workshops and group learning events, participation in social and community activities, and participation in professional organizations.

References

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