Leadership in Sustainable Infrastructure
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The uOTTAWA CAPSTONE EXPERIENCE

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Abstract: Capstone projects help prepare 4th year Civil Engineering students to begin their practice with experience in interdisciplinary teamwork, modern business practices, and a better understanding of how civil infrastructure projects are designed under complex social, environmental and economic pressures. The University of Ottawa's Department of Civil Engineering has embraced the practice of innovative, interdisciplinary Capstone projects as the best mechanism for preparing graduating civil engineers for professional and business success. Business and industry collaborators are invited to suggest projects that benefit not only the student teams, but also the business itself in terms of providing useful research, analysis and design reports. The goal is a "win-win" capstone project. Teams of 5-6 students working under the supervision of faculty advisors, over a full academic year, represents a significant benefit to collaborating agencies. This paper outlines Capstone experience gained at uOttawa, including the process, the projects, and the lessons learned in implementing design projects with a variety of collaborators.

1. Introduction

Most university engineering curricula in Canada[(1,2,3,4)] and the USA[(5)], consistent with the policies of the Canadian Engineering Accreditation Board (CEAB), now include practice-based learning in the final year of studies towards an engineering degree. Design courses attempt to cover a wide spectrum of engineering, environmental and communication skills necessary in practice, especially in Civil Engineering which has such wide interaction with public, political and regulatory agencies. Therefore programs that integrate academic learning with practical experience, under the mentorship of working professionals in industry and government, can be highly beneficial.

Capstone represents a practice based project and report capping the 4th and final year of the Civil Engineering curriculum. Capstone projects at the University of Ottawa are developed in collaboration with business, industry and government in the National Capital Region. The benefits of the Capstone process are; a) the professional development of the participating students and b) the value of a supervised team of 5-6 students working on a project of interest to the collaborator over a 24 week period.

The goal is to provide students with the opportunity to undertake Civil Engineering design projects on a team basis, in a realistic situation similar to that of a professional engineering office. By working in interdisciplinary teams and in collaboration with outside engineering firms and agencies, students learn to apply academic knowledge in an entrepreneurial manner, and to develop the teamwork, problem solving and communication skills essential for professional and career development.

2. University of Ottawa Capstone Process

In the first semester the project tenders are defined by the collaborating agencies, to which students respond with a short statement of interest. Student teams are then formed and assigned a project and an individual technical supervising professor with particular expertise in the project domain. The assigned teams subsequently prepare a proposal. The first semester culminates in a feasibility report including technical discussions, case studies and a summary comparison of the alternatives, and the preferred solution is prepared and presented. In the second semester the selected design option is developed as a detailed design and a final design report is prepared and presented.

The following table highlights the Capstone process at the University of Ottawa which includes a design course (CVG 4001) and a project course (CVG4907) over a full academic year.

Table 1: Capstone Process at the University of Ottawa

Student Activity CVG 4001 (1st term)	***Client/Collaborator Activity***
Project Tenders; Student Teaming;	*Provide data & information for project*
Inception Meeting & Discussion	*Attend meeting & provide feedback (1 hr)*
Prepare Project Proposal (10 pg)	*Review & advise via telecon/email*
Conduct Preliminary Study	*Review & advise via telecon/email*
Preliminary Study Report & Presentation	*Attend meeting & provide feedback (1 hr)*
Student Activity CVG 4907 (2nd term)	***Client/Collaborator Activity***
Conduct Detailed Analysis and Design	*Review & advise via telecon/email*
Progress Report, Review of Results	*Review & advise via telecon/email*
Capstone Design Report & Presentation	*Attend meeting & provide feedback (1 hr)*
Presentation to Collaborator Agency	*Arrange meeting & attendance (optional)*
Student Competitions, uO, PEO, CSCE	*TBD*

3. Capstone Design Course

In the first semester (CVG4001) it is intended that students be introduced to design procedures and have the opportunity to begin their Capstone designs. Students learn to develop engineering designs through a well-defined, iterative design procedure including problem identification, generation of design alternatives, selection of an optimum solution, and effective communication of the preferred solution.

Fundamental concepts are taught through formal lectures in the first half of the CVG4001 semester. Analytic tools useful in the design process are introduced, including: project management procedures such as PERT (Program Evaluation and Review Technique), idea generation techniques such as brainstorming, selection methods such as decision matrices, and optimization procedures such as linear programming and genetic algorithms. Students are also introduced to software commonly utilized for management and presentation of engineering designs. Concepts and analytic tools learned in the lectures are reinforced through problem assignments and application to the Capstone design.

Tutorial sessions are held every week during the first half of CVG4001. These sessions begin with the TA providing a brief synopsis of the salient features of the week's material. The TA will then review a few example problems, which are posted on Blackboard. Finally, these sessions will serve as Question and Answer opportunities, covering the lecture material since the previous tutorial.

The project tenders presented to the students during the first week of CVG4001 are prepared by various faculty members within Civil Engineering, including the Engineer in Residence, in collaboration with working professionals in business, government and industry in the area. The department strives to offer multidisciplinary, industry-based projects. Based on these project tenders, each student develops a statement of interest, expressing his/her preferred design projects and a justification for these choices based on the student's interests and previous experience. Student teams are free to develop their own project tender to suit their own unique interests, provided that it preserves the multidisciplinary, industry-based focus with a willing industry collaborator.

Capstone design projects are performed by groups of 4-6 students, selected at the discretion of the lecturer and the rest of the Civil Engineering faculty, with consideration of the statement of interest expressed by each student. No more than about half of the projects should be primarily focused on any one of the civil engineering sub-disciplines.

The purpose of the Proposal is to convince the proponent that the design team is the best suited to complete the design. The Proposal is intended to identify the problem, briefly discuss possible design solutions, and review the strengths of the design team in relation to this particular problem. The design teams prepare and submit their Proposal at the mid-point of CVG4001. Feedback on the Proposal is used by the design team during preparation of the Feasibility Study.

The second half of the CVG4001 semester is largely self-taught, and students are expected to work on their Feasibility Study. During this part of the semester, the scheduled lecture and tutorial times can be used to meet as a group, and teams can schedule meetings with the project supervisor, the industry collaborator or the Teaching Assistant. Some of the scheduled lecture or tutorial times in the second half of the semester are more formal, with guest lectures by visiting professionals and/or presentations by students.

The final product of CVG4001 is the Feasibility Study report for the Capstone design project. For the Feasibility Study, the design team will have gathered relevant information, developed design alternatives, made preliminary cost estimates, selected preferred alternatives, and developed a project plan for execution of the final design during CVG4907. Information gathering includes both literature searching and collection of information from the industry collaborators, as well as other relevant sources such as city planning departments, professors, etc. It is conceivable that not all relevant information will have been gathered at this stage, particularly if field data are required.

The student teams then carry through to detailed design of the selected alternative during the Capstone design course CVG4907 in the second semester. The design project is intended to be a project-based self-learning exercise with the professor responsible for the tender acting as supervisor and the industry collaborator as a mentor to the project team.

Students communicate their design projects through the written Proposal, Feasibility Study, and Detailed Design Report, and through oral presentation of the Feasibility Study, a Progress Report, and the Detailed Design Report.

4. Capstone Project Development

Capstone Projects are developed in collaboration with consulting engineers, industry and governmental organizations in the region, and ideally projects that represent “win-win” situations whereby the collaborators receive valuable analysis and preliminary design support in their own areas of interest. Every attempt is made to specify projects that are relatively wide in scope, in order to promote interdisciplinary working among the student teams of 4-6 students. Listed below are some of the recent Capstone projects undertaken by the University of Ottawa Civil Engineering students.

Stormwater Management Pond Design – Design of Stormwater Management pond or ponds for watershed undergoing development, to achieve maximum benefits including hydraulic, aesthetic, and environmental benefits. (Mississippi Valley Conservation Authority)

Low Impact Development – Design stormwater management plan with LID for existing and new urban areas of Kemptville, taking into account cost, hydrologic effectiveness, winter operation, maintenance, and environmental benefits. (Municipality of North Grenville)

Library Building Expansion - Design an expansion of an existing library building involving a series of octagonal pods, which represents a challenging design perspective. (Ottawa Public Library)

Bear Brook Flooding & Erosion – Design stream rehabilitation measures to alleviate the flooding and enhance riparian habitat of Bear Brook. (South Nation Conservation)

Wendover STEP System Design - Design upgrades and repair of the Septic Tank Effluent Pump (STEP) sewer system in the Wendover, which appears to be at the end of their useful life cycle. (Township of Alfred and Plantagenet)

Habitat for Humanity - Design of water, wastewater and stormwater services for a residential cluster community in compliance with the City of Ottawa’s design standards and availability of local infrastructure. (City of Ottawa)

Cambridge Bay Airport - Feasibility report demonstrating new construction and design methods for suitable for runways in the high arctic, and design of the preferred solution. (Indigenous and Northern Affairs Canada)

Single Span Bridge Replacement - Options analysis and detailed design of single span bridge replacement (32m span) in a small village setting. (J.L. Richards Associates)

5. Lessons Learned Through Capstone

On the positive side, the Capstone projects generate much interest and enthusiasm among both the students and the collaborators. Collaborators often attend the final team presentations, and are usually very impressed with the work of their sponsored team. The team presentations can serve as a most effective “job fair” for industry collaborators and other interested working professionals.

Also, many of the selected projects are indeed focused on the primary business interest of the collaborators, and either advance work already going on in the organization, or enable the organization to address a problem they have been unable to fund prior to the Capstone opportunity presents itself.

Most student teams work effectively together and learn the vital communication and teamwork skills they will need immediately upon graduation and entering the workplace. Out of, say 15-20 teams working at the same time, perhaps 1 or 2 teams will experience technical or interpersonal issues that may require adjustments and perhaps trading members with another team.

There does appear to be a preference among many students for more technically focused projects in the area of structural or geotechnical design, without other related components. Where a team is primarily interested in one technical area, the Department works with the team and/or the collaborator to adjust the project to suit the team, while maintaining the interdisciplinary aspect of the project as much as possible.

Sometimes, student teams require assistance in negotiating with collaborators to adjust the project to best meet the interests of both, as it can be intimidating for some teams to become involved with very busy engineering professionals and offices at this stage of their education.

Collaborating agencies have proven to be interested and involved in the work of the student teams, especially where they have been involved in project development. The best situation is one where the collaborator gains some benefit from the work of the student team, and thereby is able to accommodate the ongoing communications with the teams during what is a very busy working environment in today's engineering offices.

Finally, it is best to introduce 3rd year engineering students in some detail to the Capstone experience and the importance of interdisciplinary projects, working in teams, and communication skills to their professional development and future professional practice. This focuses their expectations on the Capstone process and its importance to their academic and practice learning opportunity.

6. Conclusions

The Capstone process represents a vital and growing component of the University of Ottawa's Civil Engineering curriculum. Every effort is made to integrate the program into the specific design courses and the expertise of the faculty, the interest and capabilities of the students, and the current infrastructure development initiatives ongoing in the National Capital Region.

Industry collaborators represent excellent mentors and sources of Capstone project tenders, and have enthusiastically supported the university's initiatives. Working with the collaborators to devise a Capstone project tender that offers both a prime student learning experience and a useful research and analysis experience for the collaborator agency.

The Capstone process at the University of Ottawa helps to provide Civil Engineering students with the skills and experience not only to build a successful career in the practice, but also to help meet the needs of Canadian society in the most sustainable manner, which is, in fact, the founding precept of the profession of Civil Engineering.

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