Planning for Success – Effective Student Proposals for Civil Engineering Capstone Design Projects

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This paper documents a pre-capstone course dedicated to student preparation of a detailed Civil Engineering capstone design project proposal, and discusses the advantages and limitations of using a proposal to define and plan an open-ended project.

Introduction

The British Columbia Institute of Technology (BCIT) launched a new four year Bachelor of Engineering (B.Eng.) program in Civil Engineering in 2006. The program was designed with the intention of achieving accreditation by the Canadian Engineering Accreditation Board (CEAB), which is responsible for identifying those engineering programs whose graduates are academically qualified to begin the process of licensure as Professional Engineers in Canada. The CEAB requires that the engineering curriculum culminate in a significant design experience based on the knowledge and skills acquired in earlier course work and which preferably exposes the students to the concepts of teamwork and project management[1].

BCIT's Civil Engineering program contains a pair of Capstone courses which include these learning objectives. The first course – Capstone Design Proposal - focuses on the definition and planning of the project the students will undertake in the following course - Capstone Design Project. Students form teams that operate like a project team in an engineering firm, and each team is managed by a self-assigned team leader. Students choose a real-life engineering design problem and are required to liaise with an industry contact. Each team is required to prepare a detailed project proposal outlining the scope of work, technical methodology, team organization and structure.

While others [2, 3] have indicated the use of proposals in a capstone course setting there has been little written about specific requirements and components of the proposals themselves or of a separate course dedicated to preparing such a proposal.

Capstone Design Proposal Course

Students in the fourth year of studies at BCIT possess strong groundwork for their capstone design project:

- As part of a dedicated second year project course students complete an individual design project obtained independently from an industry sponsor. As part of this significant project, students write a proposal describing their topic, listing the deliverables and explaining the procedures and methods being used;
- Students complete a total of four separate technical communication courses by the time they have completed year two. These are compulsory common core courses uniquely developed and offered to the Civil Engineering students;
- Students are typically mature – for example, the intake into first year Civil Engineering in September 2009 had an average age of 23 years;
- Before entering year three of the program, students are required to have a minimum of 300 hours of approved work experience or have enrolled in the 1-year Civil Engineering Internship program.

The students' very first involvement in the fourth year capstone courses actually occurs in year three, when students are required to attend the formal capstone design presentations by the senior level students. As a result, the students start thinking about their upcoming capstone course even before reaching their senior year.

The Capstone Design Proposal course is delivered in the Fall semester. Rather than using the traditional format of weekly lectures throughout the course, specific topics related to the development of the design project are discussed in a workshop format. These workshops are delivered early in the semester so as to give the students the tools they require early on. Specific topics discussed include the following:

1. Proposal writing;
2. Building teamwork skills;
3. Design project management;
4. Sustainability and engineering design; and
5. Related engineering disciplines.

Students in the Capstone Design Proposal course are given the option of obtaining their own project from industry or having one assigned to them. The requirements for project topics are as follows:

- Topics must involve real-world engineering design problems;
- Projects are done in teams of at least three (and preferably four or five) students;
- Topics must include multiple different sub-disciplines within Civil Engineering;
- The scope of work must include the investigation of design alternatives;
- The scope of work must include considerations of sustainability;
- Each individual team member should budget about 150 hrs of time during the Winter semester; and
- Topics must satisfy the CEAB significant design experience requirements (provided to the student for their reference).

The final design project proposal is actually the final deliverable in a series of incremental student submissions. Students initially prepare and submit a memo listing their team name, team members, team project manager, and out-of-class contact information. Then, after completing the Building Teamwork Skills workshop described above the teams formulate and submit their 'team contract'. This 'contract' follows a standard format[4], is signed by all team members and addresses five specific aspects of how the project team will operate – mission statement, expectations, policies and procedures, roles, and preliminary project plan.

Next, teams prepare and submit a 'preliminary proposal' – a memo providing a brief description of the topic and likely industry sponsors. These submissions incrementally prepare and position the students to be able to put together their final detailed design project proposal.

Design Proposal

The contents of the design proposal are required to match those of an industry-quality consulting engineering firm responding to a client request for proposals. Although the actual format is left up to the students, mandatory components include:

1. Project background – Why the project is needed and is relevant
2. Scope of work – What engineering design work is going to be performed
3. Work plan – How the project is going to be done, including methodologies and computer software
4. Team members – Who is involved and what responsibilities each will be filling
5. Level of effort and schedule – How long the project is going to take and how it will be scheduled
6. Fees – How much the project would cost a client if it was being performed by a consulting engineering firm

Preparation of the proposal involves consideration of the interrelation between each of the components of the proposal. Therefore, development of the proposal becomes an iterative process, as changes to one aspect of the project impact all the rest. For example, the reassignment of an individual task from one team member to another potentially affects the individual number of hours budgeted, as well as affecting the over-all schedule. Figure 1 symbolically represents the interrelation between different aspects of the proposal.

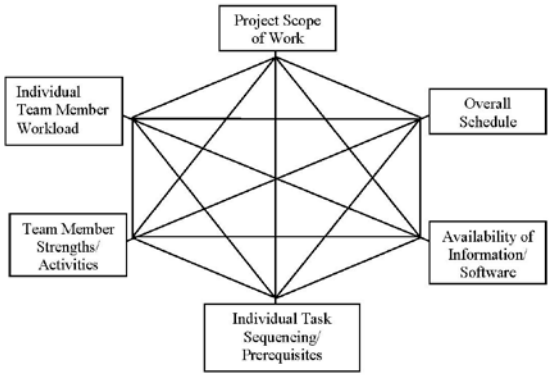

Fig. 1 – Interrelation Between Design Project Elements

As part of the proposal requirements, students prepare a detailed task list that they use to determine a consultant 'fee', using the Consulting Engineers Fee Guidelines for British Columbia[5]. Figure 2 contains an example of a portion of a student-prepared fee schedule. Individual task costs and the hourly work distribution between team members are shown. Students are also required to prepare a plot of their planned project work schedule using the Earned Value project management technique[6]. Figure 3 contains a sample plot of the budgeted cost of work scheduled (BCWS) versus time. During the following Capstone Design Project course the student project teams compare this planned work cost against their budgeted cost of work performed (BCWP) and actual cost of work performed (ACWP) during two progress presentations to identify how their design work is progressing.

Fee Schedule — **BAMM Engineering**

Still Creek Bridge Replacement, Willingdon Avenue

Task	PERSONNEL	Prime Consultant (BAMM)				Prime	Prime	Prime	Prime
		Project Manager	Municipal/Civil Design Engineer	Structural Design Engineer	Structural System Analyst	Total Hours	Labour Cost	Disburse-ments	TOTAL COST
	Assigned Personnel (initials)	AH	MC	BG	MVH				
	CHARGE OUT RATE ($/hr)	*$150.00*	*$135.00*	*$145.00*	*$125.00*				
	ACTIVITY								
FEE SCHEDULE									
1.1	**Project Initiation / Meetings**	**10**	**10**	**10**	**10**	40	$5,550		$5,550
1.2	**Prepare Base Plan**			**2**		2	$290		$290
1.3	**Hydrology**	**33**	**34**						
.1	Compile Data and Literature Review	2	2			4	$570		$570
.2	Prepare/Review Design Criteria	2	2			4	$570		$570
.3	Develop and Analyze HEC-RAS Model	12.5	12.5			25	$3,563		$3,563
.4	Preliminary Design	4	5			9	$1,275		$1,275
.5	Review	2.5	2.5			5	$713		$713
.6	Detailed Design	7.5	7.5			15	$2,138		$2,138
.7	Contingency	2.5	2.5			5	$713		$713
1.4	**Road Design**	**21**	**33**						
.1	Compile Data and Literature Review	2	2			4	$570		$570
.2	Prepare/Review Design Criteria	3	1			4	$585		$585
.3	Develop Alignment Options (horizontal and vertical)	5	10			15	$2,100		$2,100
.4	Preliminary Design	5				5	$750		$750
.5	Review		5			5	$675		$675
.6	Detailed Design	3	12			15	$2,070		$2,070
.7	Contingency	2.5	2.5			5	$713		$713
1.8	**Deliverables**	**55**	**42**	**46**	**46**				
.1	Preliminary Report	22	22	25	25	94	$13,020		$13,020
.2	Cohesion of Calculations and Drawings	1	6			7	$960		$960
.3	Report Editing	16	4	5	5	30	$4,290		$4,290
.4	Final Report	8	2	8	8	26	$3,630		$3,630
.5	Production	2	2			4	$570	$600	$1,170
.6	Presentation	6	6	8	8	28	$3,870		$3,870
	Sub-total	150	150	150	150	**600**	**$83,250**	**$600**	**$83,850**
	TOTAL DESIGN EFFORT (hours)	150	150	150	150	600			
	TOTAL LABOUR COST ($)	$22,500	$20,250	$21,750	$18,750		$83,250	$600	

Fig. 2 – Sample Capstone Proposal Fee Schedule

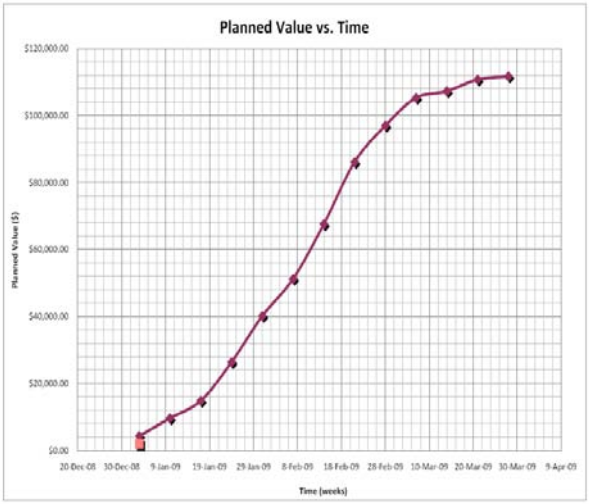

Fig. 3 – Sample Capstone Proposal Plot of Budgeted Cost of Work Scheduled (BCWS) vs. Time

Discussion

The completed proposal is submitted for review and comment by the course coordinator. After addressing coordinator comments the final proposal then serves as the work plan for the follow-up Capstone Design Project course. Additional Faculty are assigned to participate in the Capstone Design Project course in part based upon the work areas and required areas of expertise identified in the proposal submissions.

For the students, the formal creation of a work plan serves as a motivator, as they quickly realize that a just-in-time (last minute) approach to preparing the deliverables - as is often seen in other courses with smaller projects - is just not going to work for this larger scale project. Inevitably – as in the working world – the work plan and schedule are not followed perfectly, but having an initial plan in place allows for more formal and accurate tracking of progress and identification of

necessary adjustments that may need to be made as the project progresses.

In addition, considering that over 80% of the program graduates to date have entered the consulting engineering field, the preparation of the proposal document has proven to be a useful business skill. The final Capstone Design Project course submittals are required to contain an epilogue in which students perform a self-assessment of how their project progressed. In combination with the progress presentations using the earned value method to track progress, students have an opportunity to compare their actual performance to the plan that they envisioned at the proposal stage. The lessons learned from these exercise therefore provide individual feedback on their original work plan and work habits.

Developing a capstone design proposal has proven to be an excellent opportunity for the students to develop strong team-work skills that are carried on to the Capstone Design Project course and contribute to their success after graduation. A survey was conducted of 2007, 2008, and 2009 BCIT Civil Engineering graduates and employers[7] in which they were asked to comment on how well the students of the program attain a number of CEAB-defined graduate attributes. On the topic of the ability to "work effectively as a member and leader in teams, preferably in a multi-disciplinary setting", 100% of employer respondents and 96% of student respondents classified the degree to which the program had prepared the students as 'Excellent' or 'Good'. In attached responses a majority of the student comments included specific reference to the Capstone courses as contributing to this ability.

For the Course Coordinator and Faculty, the following Capstone Design Project course has run smoothly as a result of the students being more organized and prepared for their design work. There have not been any even moderately serious student issues in the four years of offering the Capstone Design Proposal and Capstone Design Project courses. The formal proposal requirement has also given the students more freedom in choosing topics of interest instead of being limited to assigned projects. Interestingly, despite being presented the option of undertaking assigned problems or choosing their own project, 100% of students to date (a total of twelve student design teams over four years) have opted to choose their own projects. The author's own sample survey of Capstone projects in Canadian universities and later work by Howe and Wilbarger on Capstone Courses in the U.S.[8] indicate that the approach of having students obtain their own projects is in the minority. Nonetheless, this approach has been continued at BCIT because of the success of the Capstone Design Proposal course.

Conclusion

The senior-level students have successfully identified, defined, and planned capstone projects with the guidance of the capstone proposal course described above. The course structure permits the iterative development of the detailed proposal, and perhaps the most important aspect of the proposal itself is the students' realization and appreciation of the inter-relation between different tasks, schedule and scope of work. In addressing these issues the students create a work-plan that they can follow in their Capstone Design Project course. The course and format presented here could easily be adaptable to other disciplines of engineering, and provides mutual benefits to the participating students and directing faculty.

References

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