Developing a Workable Senior Construction Management Capstone Project

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Abstract

A senior capstone course should challenge students to use the skills that they have developed in their college experience. Because construction management curricula is so diversified, senior capstone projects have to be practical exercises that incorporate both business principles and professional construction management practice. In the spring 2004 semester at the University of Maine, a construction management capstone class was developed that utilized major components needed in modern construction practice. Student teams were assigned to develop capstone projects based on actual plans and specifications that were either actively being bid or constructed in the public sector. Plans represented various project types and included a municipal wastewater treatment plant, an interstate bridge, and a highway embankment

Students formed groups who took the identity of various active contractors. The capstone consisted of these individual teams choosing a set of plans and specifications from the varied set of available plans and preparing for four project phases: a business plan, project bid, construction schedule, and after construction litigation. Because of the size of these projects and the time limitations of the semester, selected areas of the plans were bid and scheduled. Bidding required each team to create a bid book that documented all assumptions and presented the costs as per required in the contract. The bid was awarded and the teams then prepared a resource loaded construction schedule. Scenarios were created for litigation and the teams outlined how they would defend against the litigation. Guest speakers came to class sessions to discuss business plans, business research, construction project management, and QC/QA control. Students were graded as teams and were judged on the separate four phases.

Introduction

The Construction Management Technology (CMT) Program at the University of Maine offers students a combination of Civil Engineering and Business Management courses that ultimately lead to a BS degree in Construction Management Technology with a minor in Business Administration. Upon graduation, CMT students are prepared to take active roles in managing and supervising construction projects. The CMT program at UMaine is ABET accredited and is actively mentored by an industrial advisory committee formed by leaders in the greater construction community. Throughout their four years in the program, CMT students are exposed to a variety of courses, summer job experiences, and professional interaction with the construction industry. To bring all of these diverse experiences together, the UMaine CMT program requires all graduating seniors to participate in a senior capstone course that highlights

the major areas within the curriculum. This paper will discuss the development of the semester long 2004 capstone course and the four phases used for student assignments.

Background

The overall development of the 2004 capstone course was founded in several TC2K/ABET criterion 2 objectives. Each objective provided guidance in both the overall format of the course and the specific assignments used in the phases that were implemented. The following ABET objectives were applied:

a. demonstrate an appropriate mastery of the knowledge, techniques, skills, and modern tools of their discipline,
b. apply current knowledge and adapt to emerging applications of mathematics, science, engineering, and technology,
d. apply creativity in the design of systems, components, or processes appropriate to program objectives,
e. function effectively on teams,
f. identify, analyze, and solve technical problems,
g. communicate effectively,
i. understand professional, ethical, and social responsibilities

The course was structured with a combination of guest speakers and active hands-on exercises in which students could apply their knowledge of the principles of construction management. On the first day of classes, students divided into groups of their own choosing of up to five members. As discussed by Tooley and Hall of Arkansas[1], student teams are important within capstone experiences to illustrate the diversity in the workforce. Teams must come together to successfully accomplish tasks.

The student groups then chose corporate identities from a master listing of some of the major large and midsized New England construction companies. Each group assumed the identity of the chosen contractor and was assigned to research corporate information about that contractor. The group used their chosen company identity for the exercises used throughout the semester.

Phase 1

Under the first phase of the course, the construction teams were introduced to the business aspects of a modern construction company. The intent of this phase was to meet ABET objectives a, e, and i. Each student had taken a variety of business courses that gave background information on business practice, but these courses don't incorporate issues related to construction practice. A two part exercise was assigned to give students an opportunity to incorporate business principles for their respective construction companies. The first part of the exercise required the individual group to devise a 5 year business plan for their company. This plan needed to look at the present situation of the company, the potential market trends, and the potential expansion opportunities. The second part of the exercise required the group to find available information about the company to complete a surety bond application. These applications require extensive information about the financial and physical assets of a company.

This two part exercise demonstrated the need to devise a plan of action and to maintain a working knowledge of company assets.

To prepare for the exercise, a business librarian and a technical librarian from the University of Maine Library spoke to the class about the available resources available at the university library. Students were shown indexes and databases in which they could find information about the companies that they represented. The librarians also showed information about financial markets and the trends of different types of industry. A business professor who specializes in small business development also spoke to the class about some of the areas that one considers in putting together a business plan. The students were introduced to the types of financial information that are required for business loans and application. He showed the make-up of a business plan and explained how these plans are used to form the strategies that a company follows for development.

Students were given three weeks to complete the phase 1 exercises. The deliverables that each group submitted consisted of a business plan as defined by the group and a surety bond application as given in an electronic template form through Zurich Surety Bonds.

The business plan and bond application were evaluated through a subjective rubric that analyzed the deliverables based on company history, market considerations, competition overview, and established goals. Each of these criteria was rated on a 1 to 5 scale with 1 as lowest and 5 as highest. The overall presentation was additionally rated on graphics and readability on a parallel 1 to 5 scale. General comments and criticisms were also provided. Giolma and Nickels of Trinity University[2] point out that varied written reports at the end of each section of a multi phased capstone project are important feedback instruments. The reports force students to evaluate the progress of the capstone as the capstone is developed.

Deliverables were evaluated based on the perspectives of a financial evaluator who doesn't know the construction industry. Company history, competition, and market evaluation were the main areas for consideration. Six teams were evaluated and two were rejected as non-bondable. These teams were criticized for weak market evaluation and undefined goals. They were advised to develop stronger market research and to better understand their respective company limitations. The other four teams were considered bondable, but it was noted that the market considerations should be re-evaluated to consider possible expansion opportunities. One group made contact with the company whose identity they chose and looked at a potential business plan with company representatives. These students gained some insight into inside information not found in the public record.

Phase 2

The second phase of the course consisted of having the teams prepare a construction bid on an active public works project using the knowledge of the company that they represented. The intent of this phase was to meet ABET objectives b, d, e, f, and g. Each student had taken a course in project cost estimation, but had not had practical limitations imposed on class exercises as would a company of limited resources and expertise. Students were given the choice of bidding the renovation of a sewage treatment plant, the rehabilitation of a concrete bridge

structure, or the earth embankment approach fills for a bridge structure. These projects had estimated dollar values of between $2 and $7 million and represented both horizontal and vertical construction.

To prepare for the exercise, a project manager from a local construction company presented to the class the considerations that he goes through in putting together a construction project. The complete plans and specifications for each project were provided and a general overview of each project was given by the instructor. The teams were required to choose one project such that only two groups worked on any one of the respective three available projects. Again, the groups were to bid the respective project as if they were the company that they represented, i.e. they knew financial and physical assets of their respective company. Because of limited time and the complexity of the respective projects, teams were told to concentrate on the pricing of instructor selected items.

Required deliverables for the estimate consisted of a bidding book that showed quantity take-off, referenced pricing, and overall assumptions. Students also needed to provide sheets with errors and omissions, subcontractor proposals, and material quotes. Groups additionally provided a call record for contacts with subs and owners. As part of the exercise, the bid book also included a bid bond and performance bond.

The bid book was graded using a rubric similar to that used in phase 1. Evaluation areas included the consistency in take-offs, practicality of assumptions, and price quotations. The book was also graded on overall presentation that included referencing and accuracy. The actual bid number was compared bid numbers from the real bid project. Students were encouraged to obtain information from real subcontractors and material suppliers.

Bid books were evaluated from the perspective of the owner of a construction company. This perspective reviews completeness of the final bid such that the company can minimize expenditures and not compromise quality. A complete document supports how the company will proceed with the project. The six groups all provided acceptable bid books. Weaknesses included thorough documentation of assumptions and referencing bid prices. The student prices were generally within the range of actual bids received for the various projects. Two teams contacted subcontractors and material suppliers to assist in the bids. One team contacted the engineer/owner to inquire about possible plan errors.

Phase 3

The third phase of the course consisted of having the student groups take their respective bids that they completed in phase 2 and scheduling the project as if they were building it. The intent was to have students meet ABET objectives a, e, f, and g. Each student had recently taken a course in construction scheduling and this phase was used to reinforce their understanding of scheduling practices using Primavera P3 software. Under the criteria of the project, students needed to cost and resources load the various items of the schedule as if they were the actual contractor that they represented.

To prepare for this exercise, a Federal Highway Administration Engineer presented Quality Control/Quality Assurance program requirements to the class. This presentation gave students an overview of QC/QA plans that contractors need to develop on federally funded projects. As part of the schedule, the QC/QA plan must be adequately planned upfront or the testing protocols becomes part of the critical path. Though not integrated into the class exercise, QC/QA and traffic control plans are essential components of the contract schedule.

Deliverables included a Primavera P3 generated schedule with resource loaded printouts. The critical events were marked and an overall time duration was developed. Students were further required to provide any assumptions that were made in developing the schedule such as duration information and activity sequences.

A rubric was used to review each of the group schedules. This rubric looked at the logic of the presentation, the realistic duration, and use of limited resources. These books were reviewed from the perspective of the construction company owner. The underlying review was on realistic construction practice.

All groups did well in scheduling the project. The areas that were scheduled were logically sequenced and organized to follow assumptions within the constraints of available resources. Weaknesses were in integrating the isolated areas of the schedule that were developed into the larger picture. Because of the limited time of the semester, students were not required to schedule the whole project; but rather, a portion of the schedule that the instructor chose.

Phase 4

The final phase of the course consisted of having the student groups refute a claim for their respective project. Scenarios were created for each of the projects and teams were required to develop a response that could be used in arbitration. The intent of this exercise was to have students meet ABET objectives a, f, g, and i. Because the semester was rapidly drawing to a close at the time of phase 4, the exercise was a team writing assignment. The arbitration was simply the construction company writing a defense to refute the claims presented in the scenario. The instructor took the position of a third party arbitrator. Using a rubric, student teams were judged based on logic of their argument, the approach to supporting the contractor's position, and the overall presentation.

Student groups were all judged to favor the contractor's position. Weaknesses were in the written style that the groups used in providing a clear argument.

Conclusion

An effective senior capstone project used in construction management technology programs incorporates both presentations from practicing professionals and "hands on" exercises for students. Under a four phase development, students use skills learned in coursework to demonstrate management practice within a 15 week semester. These phases include business plan development, cost estimation, project scheduling, and project arbitration.

The development of such a capstone course is best created in conjunction with ABET objectives. These objectives help formulate the learning outcomes that should be expected from a group of graduating seniors in a construction management program.

The use of a four phase capstone project using ABET objectives was successful at the University of Maine. Through teamwork, students followed an abbreviated project from beginning to arbitration. They used the limited resources of construction companies to develop realistic business plans through to applying resources to the bidding and scheduling of an actual project.

Bibliography

1. M. Tooley and K. Hall. Using a Capstone Design Course to Facilitate ABET 2000 Program Outcomes. In *Proceedings-ASEE Annual Conference and Exposition 1999*, < http://www.asee.org/acPapers/99conf535.PDF>, accessed January 15, 2005.
2. J. Giolma and K. Nickels. Herding cats: a case study of a capstone design course. In *Proceedings-ASEE Annual Conference and Exposition 2002*, < http://www.asee.org/about/events/conferences/annual/pdf/upload/2002-PIC-II-Best-Paper.pdf>, accessed January 15, 2005.

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Biography

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