STUDENT-CENTERED LEARNING ENVIRONMENT DURING UNDERGRADUATE EDUCATION IN CONSTRUCTION ENGINEERING AND MANAGEMENT – DEVELOPING A CONSTRUCTION CONSULTING PROJECT

Gunnar Lucko

ABSTRACT

Construction engineering and management education is facing special challenges that lie within the nature of the subject area itself. Construction is a highly interdisciplinary profession whose body of knowledge has grown since its formal conception several decades ago to reflect the manifold dimensions of the projects that construction engineers and construction managers are controlling. New learning models need to be explored in teaching to avert the risk of conveying this knowledge to students at the undergraduate level in a fragmented and irrelevant manner.

This paper presents an innovative teamwork approach used in a sequence of two undergraduate construction courses at The Catholic University of America (CUA). Following an introduction of student-centered learning, the Construction Management Consulting Project is outlined in its major phases and features, including its realistic scenarios, its modular integration with classroom knowledge, and its review and final documentation. They are linked with the six levels of competence in Bloom’s taxonomy of learning and consider different learning styles. Research studies have confirmed the success of such project-based and student-centered learning environments. The paper concludes with feedback from students and with recommendations for implementing learning experiences that actively engage students to grow into the leaders of tomorrow’s construction industry.

INTRODUCTION

Construction engineering and management education needs to give students the technical and personal skills for being successful in a practical work environment where they will solve real problems in the complex interplay of the various dimensions of the project. Construction itself is the youngest and most interdisciplinary specialization within civil engineering. Its research areas and teaching agendas have been developing dynamically since its inception as a separate discipline. Characteristic are the breadth of topics that it encompasses, e.g. scheduling, estimating, operations planning, and contract administration, and the many additional fields from which it draws specialized knowledge applicable to the successful planning and execution of construction projects. For construction courses in an undergraduate curriculum this wide array of topics poses a challenge to not present a fragmented accumulation of the construction body of knowledge within the limited amount of time, but to achieve a meaningful and deep integration.

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NEEDS IN CONSTRUCTION EDUCATION

Several authors have contemplated the current situation and future demands on education in construction engineering and management. Bordogna (1998, p48) argues that in light of the “increasingly complex and interconnected” nature of the systems that sustain our lifestyle in its “social, economic, environmental, legal, and political” setting, there is an ever-growing need to provide an educational training ground where future engineers can obtain “a broad, holistic background” and develop integrated skills. He criticizes that “[p]resent curricula require students to learn in unconnected pieces, separate courses whose relationships to one another and to the engineering process are not explained until late in a baccalaureate education, if ever” and calls for ways to allow students to become “master integrators” (Bordogna 1998, p49-50). Earlier, Jester (1990) had encouraged bringing a stronger systems perspective into the civil engineering curriculum. Fondahl (1991) had also emphasized developing teamwork skills in students to prepare them for their roles in the professional relationship between owner, engineer, and contractor. The consensus nowadays is that communication, teamwork, systemic thinking, creativity and an understanding of societal issues are important pieces of engineering education, adding value to the traditional analytical emphasis on mathematics and the natural sciences. More than ever before the old saying applies that engineers are hired for their technical skills, fired for their lack of people skills, and promoted for their management and leadership skills.

Sawhney and Mund (1998, p1319) stressed previous research findings that “students learn more effectively and permanently when they can actively participate in the learning process” and underlined the need for integrated learning, as “curricula do not give students a holistic view of their field of study” but fragment the information into many specialized but unconnected courses. Senior (1997, p45), in his discussion of simulations and case-based instruction in construction, is of the opinion that “[p]RACTICAL ACTIVITIES ARE PROBABLY MORE IMPORTANT THAN THEORY IN THIS FIELD.” Chinowsky and Vanegas (1996) support returning to an educational approach that is generalist and sought by industry employers, noting that the focus on modeling and simulation of construction operations has furthered the fragmentation. The consulting project described in this paper turns their vision of an integrated learning system specifically for construction management into reality. In particular, different from the case studies criticized by Rojas and Mukherjee (2005) as being limited due to missing context, the consulting project provides a rich situational learning environment in which the students themselves create most of the materials under the guidance of the instructor.

Student-Centered Learning Philosophy

Student-centered learning is an approach that reconciles the confusion that oftentimes exists in the exact use of the terms teaching and learning. Using the analogy of manufacturing for the educational process, teaching is to learning what the process is to the product. One could also compare the teacher-centered style to a ‘push’ model in the manufacturing chain and the student-centered style to a ‘pull’ model. Cannon (2000) defines student-centered learning as a new way of thinking about education:
Student-centred learning describes ways of thinking about learning and teaching that emphasise student responsibility for such activities as planning learning, interacting with teachers, and other students, researching, and assessing learning.

The student-centered learning philosophy thus puts much weight on the students as the clients and beneficiaries of, and indeed the reason for the entire educational process. Since students are given more freedom and responsibility for their own learning progress under this approach and are expected to be active participants rather than merely passive recipients, it may initially be met with uncertainty and irritation by them. However, numerous studies, e.g. Barr and Tagg (1995) have shown that student-centered learning yields more lasting educational experiences, as the students themselves will eventually perceive the value of being actively involved in their own learning, e.g. through creating study materials themselves, and will consider it more rewarding. Clearly, it also places higher expectations on the teacher, who can no longer recite a much-repeated monologue anymore but rather has to carefully and flexibly guide students in “learning how to learn” by using the particular topic at hand as sample contents to practice this new skill. Instructors will have to be more creative in their evaluation of the broad spectrum of work products that their students generate, which will no longer be so straightforward, e.g. answers to true/false questions. As demonstrated in this paper, it is possible to evaluate students just as clearly under the student-centered approach as under the teacher-centered approach with its traditional assessment methods.

The spirit of student-centered learning is fully reflected in the eleven Engineering Criteria 2000 of the Accreditation Board for Engineering and Technology (ABET), whose new approach focuses on learning outcome (Abudayyeh et al. 2000), not on teaching input, and includes problem solving in teamwork among its requirements. As Cannon (2000) explains, project-based instruction is an excellent way to incorporate student-centered learning into an engineering curriculum. The following sections describe the innovative student-centered approach of the construction management consulting project (CMCP), an extensive teamwork activity spanning two consecutive undergraduate courses of the Construction Engineering and Management Program at The Catholic University of America (CUA).

CONSULTING PROJECT FEATURES

The semester project is a semi-realistic construction project. Working in teams of four, students act as construction management consultants (CMC) to the owner, who in this role-play is embodied by the instructor. The CMC teams are tasked with developing full guidelines for a successful execution and completion of their project. The results of these efforts are documented in a comprehensive project execution manual. The design only is taken to the level of detail of line drawings with a plan view of the space layout and landscaping and elevations of the structure. The following table of contents lists items addressed by the CMC teams in order of their typical occurrence in the project delivery process: Feasibility, marketing, and environmental impact studies, preliminary design and specifications, engineering, estimating and bid preparation, permits and approvals, financing arrangements, planning, organizational structure and interface coordination, staffing, suppliers and
procurement, schedule preparation with milestones and incentives, contract development and administration, construction means and methods, safety program, quality control, development of project controls, turnover and start-up preparations, facility operations and maintenance, cash flow forecasting, and other requirements as deemed necessary. Specifics of the project and its site are a combination of actual data, e.g. materials and labor costs, and justifiable engineering assumptions, e.g. forecasted rental or sales revenues. The estimate and schedule are based on a preliminary take-off with about 75 activities. Scenarios include a new engineering building at CUA, a 15,000 m² two-story anchor store for a mall, an upper-scale fitness and health spa club, a country club with support facilities, a 10,000 m² multi-story senior citizens’ residence, and a 250-slip marina to dock and service pleasure craft.

Levels of Learning and Project Elements

Bloom’s (1984) classic taxonomy of learning has been implemented in designing countless educational programs. Its hierarchical levels of competence have also been used in the elements of the consulting project as shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1: Bloom’s Taxonomy of Learning and CMCP Elements</th>
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<td>(Adapted from Bloom 1984)</td>
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<table>
<thead>
<tr>
<th>Level</th>
<th>Competence</th>
<th>Instructional Activities</th>
<th>CMCP Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Evaluation</td>
<td>Critique, evaluate, justify, optimize</td>
<td>Progress review, incorporation of feedback</td>
</tr>
<tr>
<td>5</td>
<td>Synthesis</td>
<td>Create, design, formulate, propose</td>
<td>Project specifics development, data research for scenario</td>
</tr>
<tr>
<td>4</td>
<td>Analysis</td>
<td>Classify, derive, predict</td>
<td>Feasibility, marketing, and environmental impact studies</td>
</tr>
<tr>
<td>3</td>
<td>Application</td>
<td>Apply, calculate, solve</td>
<td>Cost estimate and construction schedule development</td>
</tr>
<tr>
<td>2</td>
<td>Comprehension</td>
<td>Describe, distinguish, explain, paraphrase</td>
<td>Project presentation, project execution manual</td>
</tr>
<tr>
<td>1</td>
<td>Knowledge</td>
<td>Identify, list, outline, recite</td>
<td>Project phases breakdown, specifications</td>
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It has been noted that a discrepancy may exist between the traditional teaching styles of professors and the predominant learning styles of students. Recognizing that learning is “a two-step process involving the reception and processing of information,” Felder and Silverman (1988, p674) revised early models of learning styles that were based purely on the human senses, leading to the well-published distinction into visual, auditory, and tactile or kinesthetic learners, and developed a model that in its updated form comprises four dimensions. These are perception, input, processing, and understanding with their respective individual preferences of sensing or intuitive learning, visual or verbal learning, active or reflective learning, and sequential or global learning. The elements of the consulting project have been specifically designed to address such different learning styles as listed in Table 2.
Table 2: Learning Styles and CMCP Phases  
(Adapted from Felder and Silverman 1988)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Preferences</th>
<th>CMCP Elements</th>
</tr>
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<tbody>
<tr>
<td>Perception</td>
<td>Sensing</td>
<td>Design drawings and descriptions</td>
</tr>
<tr>
<td></td>
<td>Intuitive</td>
<td>Creative development of specifics</td>
</tr>
<tr>
<td>Input</td>
<td>Visual</td>
<td>Visiting location, design development</td>
</tr>
<tr>
<td></td>
<td>Verbal</td>
<td>Project presentation, review session</td>
</tr>
<tr>
<td>Processing</td>
<td>Active</td>
<td>Teamwork, discussions</td>
</tr>
<tr>
<td></td>
<td>Reflective</td>
<td>Incorporation of feedback</td>
</tr>
<tr>
<td>Understanding</td>
<td>Sequential</td>
<td>Lecture series, project life-cycle steps</td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>Project execution manual</td>
</tr>
</tbody>
</table>

**Project Phases**

Both civil engineering and architecture students enrolled in this cross-listed course sequence. Their different backgrounds were taken into consideration when CMC team assignments were made, enabling them to gain from each other’s diverse skills. The following sections outline the individual project phases and features. Regular lectures, including guest lectures by industry experts and visits at various types of construction sites, continued during the project work in topical modules that built on the previous semester in a sequence that was coordinated with the developing project materials. Project activities were woven into the schedule to complement the classroom sessions.

*Initial Work and Consulting*

At the onset of the project, the owner and the CMC teams extensively discussed the desired nature of the completed facilities with respect to scope, location, design, and functional details. Afterwards, the owner was flexibly available as requested by the CMC teams. While not required in the original assignment, several CMC teams visited their respective project location, investigated its surroundings, and selected a specific site, which they documented in digital photos and later included in the project execution manual, in some cases with CAD renderings inserted into the photos.

*Progress Review and Report*

About halfway through the consulting project the CMC teams participated in a progress review to keep the owner informed of the progress achieved in planning the project. Part of the review was the written progress report with a depth approximately equivalent to a 50% design review. It contained at least a formal description of the progress, areas identified to still be addressed, major concerns and suggested solutions, and aspects of the project that are typically completed at an early date, e.g. location and environmental setting, a preliminary design contract type, organizational structure, and feasibility, marketing, and environmental impact studies.

The CMC teams met with the owner in a review session for which they were asked to select and formally present specific issues. Should competing options exist for a particular issue they were asked to develop such alternatives in sufficient detail, present their advantages and disadvantages to the owner, and receive guidance in
choosing. Each team was given extensive feedback, both during the meeting as well as in written comments, on the work that they had performed, and directions for continuation of the work and potential areas of improvement.

Project Execution Manual and Presentation

At the conclusion of the two-semester course sequence, the CMC teams prepared a project execution manual with its detailed explanations of each topic. A sample table of contents as listed above under Consulting Project Features had been provided. The teams were briefed about elements of good presentations, effective use of visual aids, and rhetorics skills to prepare them for their oral 25-minute presentations. Presentations required participation of all team members and were open to the university public. The School of Engineering at CUA was equipped with several “smart classrooms” whose information technology the teams could use for their presentations. Audience members commented favorably on the quality of the work products and the professionalism with which they were presented. Evaluation and grading of the manual and the presentation strongly considered that in reality these materials should ultimately convince the owner to hire the CMC team as experts for consulting on the actual construction project.

Assessment Techniques

All aspects of the consulting project are considered to determine the overall grade. A detailed catalog of evaluation criteria, each with their relative weights, for all individual work products is distributed at the onset of the project work. Criteria cover the completeness and structure of the contents and the accessibility and clarity of its communication. Additional materials with specific information on how to produce different types of professional quality engineering submittals are made available to the CMC teams. Work that goes beyond the announced requirements and adds relevant new dimensions to the individual project scenarios can receive partial extra credit to stimulate and reward creativity.

STUDENT FEEDBACK

Anonymous feedback was solicited from the students to obtain the widest range of possible comments. An intermediate survey questionnaire with open-ended questions was distributed at mid-semester and a survey was again distributed at the conclusion of each semester in addition to the official university course evaluation. These snapshots of the students’ perception allowed gaining insights into developments during the project. The following representative transcriptions are a sampling of the students’ reflections on the course sequence, the consulting project, communication, and teamwork from both the original course evaluations and from the surveys.

Please give your opinion about the course:
The project helped in pulling everything together[.] Helped in my greater understanding of the basic fundamentals of const.[ruction] management[.]

What is the idea or concept that will stay with you the longest?
The concept of working as a group. The group project helped me understand the complete concept of const. management.
The semester project helped me understand the construction process very well.
What have you learned about construction management through this semester project?
I learned a lot about the overall construction process and all that is involved in getting a project off the ground. 
Amount of planning + coordination that goes into construction B4 [before] construction + the importance to do so.
There is a lot that goes into a project. Communication is probably the most important part of construction management.

What have you learned about teamwork through this semester project?
it is difficult to coordinate Architect + Engineers, especially when randomly chosen.
that commitment, flexibility, and fairness is essential for a team project's success.
It’s not easy, but with good communication you can have a successful project.

A former student who now works as an Office Engineer with a major construction contracting company wrote in retrospective:

The project definitely helped in the bringing together of the various aspects and smaller disciplines that make up construction management as a whole. Being able to see and help guide a project from a concept to a reality proved very exciting, but for me however, the most important aspect was the opportunity to function as part of a team. Evaluating the team members, focusing everyone on their individual strengths and coming together for brainstorming sessions is what I believe led to successful project. It was seen then and I’ve seen it since on other projects, both in school and in the field.

As a personal note, I believe it helped quite a few of us realize that we are all capable of emerging as valuable contributors to a project team. This role is key on construction sites and also for one's own personal advancement. The ability to draw and learn from those whom we work with has proven invaluable in both my past and current position, and I am of the belief that it began during my academic career by participating in assignments such as the CM Consulting Project.

Quintin K. Hackshaw, Class of 2005

RECOMMENDATIONS AND CONCLUSION
Based on several years’ worth of experience since first implementing the consulting project at CUA, the author believes that it offers the opportunity for a rich educational experience in a fully student-centered learning environment. If implemented at a university program in construction engineering and management, its semi-realistic project scenarios should be located in the vicinity of the campus so that the students on the CMC teams can relate to the location, and through visiting it and researching actual data pertaining to the particular site achieve a degree of realism that is just one step below performing real field work for a construction contractor during a summer internship. One improvement planned for upcoming iterations of the consulting project is stronger industry involvement. Representatives of the regional construction industry, e.g. from the departmental advisory board as recommended by Abudayyeh
et al. (2000) or from the many CUA alumni in the metropolitan region, could become engaged beyond serving as guest speakers; rather, the CMC teams could be assigned industry mentors who could share their experiences during project development, facilitate visits to the offices of construction management companies, and would also form an expert panel to whom the final presentation is given. Moreover, student comments support the addition of a peer evaluation component to the overall assessment, including self-evaluation of their own performance as described by Riley et al. (2004). Such team evaluation can use a range of questions that measure various aspects of the teamwork. Each question would carry 100 points that the students distribute among all team members. Equal points would represent equal contributions by each team member. The instructor then calculates the average percent for each person and multiplies it with the project grade to obtain the individual grades. Open-ended questions should be included in the questionnaire to capture any issues that the students consider essential in reflecting upon their learning experience with the consulting project.

ACKNOWLEDGEMENT

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