Problem-Based Learning as Applied to the Construction and Engineering Capstone Course at North Dakota State University

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Introduction

The Department of Civil Engineering and Construction at North Dakota State University consists of two divisions, the Division of Construction Management and Engineering and the Division of Civil Engineering. Prior to 1998, the Department had three separate capstone courses for each degree program (construction engineering, construction management, and civil engineering). During the Spring Semester of 1998, a single overall departmental capstone course was created. The intent was to provide a true “capstone” experience, where students in each degree program could combine their skills to achieve the successful completion of a project. The primary objective of the capstone experience is to combine all aspects of the planning, design, and construction phases of a project into meaningful education experience which mimics “real-world” design and construction practices. Students are required to use all of the knowledge and skills that they have acquired throughout their educational experience to develop the documentation required for actual project construction (design drawings, cost estimates, project schedules, quality and safety plans, etc.). The intent of the capstone experience is to integrate the engineering and management disciplines into a single comprehensive educational experience.

North Dakota State University (NDSU) was the recent recipient of a Bush Grant for providing support and training for NDSU faculty. As part of that grant, the “Faculty Institute for Excellence in Learning” (FIEL) was created. The author was selected as a FIEL “Fellow” and subsequently submitted a proposal and received funding to apply a problem-based learning approach to the departmental capstone course. During the summer of 2001, the capstone course was revised and restructured to meet the primary objective of the course. The basic philosophy, format, evaluation and assessment of the course came into question. The contents of this paper, 1.) describe some of the philosophical questions that had to be addressed, 2.) provide an overview of problem-based learning, 3.) explain the revised course content and delivery systems, and 4.) provide an explanation of the techniques used to evaluate student work and provide course assessment.

Philosophical Questions

A number of meetings were held to determine the exact role and function of the capstone experience. Initially, fundamental philosophical questions had to be addressed by the faculty. For example, what should be the overall structure of the course and how is this tied to the course objectives?, what is the basic instructional format?, what are the purpose and function of the group and class meetings?, what is the role of the instructional staff?, should and will the expertise of other faculty be required?, what is the role of guest / industry speakers?, and is there a need for faculty advisors for each group? Along with the discussion that followed these questions, the issues of evaluation, assessment and information access were also discussed. For example, how will the student work be evaluated and by whom?, how will information be accessed by the students (Blackboard Course-Info, www, share directory, hard copy in library, distributed in class)?, how will course assessment be accomplished?, how will previous course assessment be incorporated into subsequent course offerings?, and how can the assessment be tied to the Annual Departmental Assessment Report and the ABET & ACCE reports? After much discussion, it was determined that the basic approach that should be used in the capstone course would incorporate the methods of problem-based learning.

Why Problem-Based Learning? (1,2)

In June of 1994, the Wingspread Conference brought together state and federal policy makers, and leaders from the corporate, philanthropic, higher education, and accreditation communities to discuss “quality” in undergraduate education. The discussion that took place was based on the assertion that there exists a substantial need for improvement in American undergraduate education in order to meet the needs of today's business and industry.

The conference developed the following list of important characteristics of quality performance of college and university graduates:

- ▶ High level of communication skills.
- ▶ Ability to define problems, gather and evaluate information, develop solutions.
- ▶ Team skills (the ability to work with others).
- ▶ Ability to use all of the above to address problems in a complex real-world setting.

Problem-based learning (PBL) techniques help students develop the above skills necessary in order to succeed in their post college careers. Students in PBL courses are challenged to "learn to learn" so that they can achieve their highest potential in their chosen professions. Students work cooperatively in groups, seeking solutions to "real world" problems by asking and answering their own and their peers' questions. In helping to teach each other, students achieve a high level of comprehension of the concepts of the course.

PBL - Roles And Procedures

PBL is an instructional method characterized by the use of “real world” problems as a context to learn critical thinking, problem solving skills, and acquire knowledge of the essential concepts of the course. Arguably, there is a gray area between problem-based learning and other forms of cooperative or active learning due to the facts that they share certain common features and hybrid approaches are formed as course instructors adapt methods for particular situations. However, in PBL the problem comes first, which contrasts with teaching strategies where concepts are presented in a lecture format followed by "end-of-chapter" problems (3). In PBL, students working in small groups must identify what they know, and more importantly, what they don't know and must learn in order to solve a problem. The scope and nature of the problem preclude simple answers. Students must go beyond the textbooks to collect information and knowledge from a variety of resources. The primary role of the instructor is to act as a facilitator for the overall group process and stimulate and direct learning. The basic features of PBL are:

- ▶ Learning is initiated by a problem.
- ▶ Problems are based on real-life, open-ended situations.
- ▶ Students identify and locate the resources required to solve the problem
- ▶ Students work in small permanent groups with access to an instructor.
- ▶ Learning is active, integrated, cumulative, and connected.

Typically, a class is divided into groups of approximately four or five students. These are usually permanent groups whose membership remains constant throughout the semester. At the purest level of PBL, the groups define the "learning issues" that they believe are at the core of each problem. The groups then decide how to divide their labors to resolve these issues.

Course Delivery System

Once it was determined that PBL was the appropriate format for our capstone course, the actual structure of the problem and the delivery of relevant information had to be determined. An alliance was formulated between the Department and representatives from YHR Partners, Ulteig Engineering, the City of Moorhead, MN, Cass County, MN, and MN DOT. The actual real world project was the Moorhead Joint Use Public Works Facility. Basic problem information for the project was provided by industry members. As is the case with the design and construction of many buildings, the architect completes the building design while the engineering firm performs the calculations and design work for the structure, the building systems, and the site work. This is the problem that our students faced. Given an architectural concept and a plot of land, what knowledge and information do they need to complete the engineering design of the building (and the site), to determine a work plan (sequence), and to estimate project cost and time?

The basic project information provided by project participants included typical information that is available to the engineering firm (architectural CAD drawings, a geotechnical report, very basic project specifications, a plat map, and a topography map). All of this information was in electronic format and could be accessed by the groups using Course Info. The information was centrally located in order to minimize repeated, and possibly disruptive, contact between student groups and industry professionals.

For the capstone course, students were assigned to groups of four or five students per group. Since there were twenty-one students in the course, we used four groups of four students and one group of five students. The instructional staff assigned the students to each group based on their major and previous course work. The intent was to achieve a balance of construction and engineering students within each group. The student groups were responsible for developing the “learning issues” that they believed were fundamental for completing the problem. In addition, they had to define what information was needed for the problem, where they could find it, and how were they to properly use that information in the context of the problem. Initially, they were not aware of the information that could be accessed through Course Info. In order to promote effective group work, several team building exercises were incorporated into the initial phases of the course. Table 1 presents a basic outline of the capstone course.

Table 1 Basic Course Outline

Introductions and Team Formation	Week 1
Team Building Exercises	Weeks 1&2
Project Requirements and Resources	Weeks 2&3
Basic Work Plan, Preliminary Cost and Time Estimates	Weeks 3-6
Site Layout/Design and Constructibility Reviews	Weeks 6-8
Building Interior and Exterior Design	Weeks 9-12
Overall Engineering Design, Revised Cost and Time Estimates	Weeks 12-14
Final Report	Week 15

In order to check student progress, a number of written status reports were required to be submitted throughout the semester. Additionally, two oral presentations were scheduled for each group as well as a final written report. Peer evaluation of group members also contributed to the student grade, as indicated in Table 2 on the following page.

Table 2 Grading Criteria and Basic Deliverables

Status Report No. 1	10%
(Work Plan, Cost Estimate, and Project Schedule)	
Status Report No. 2	10%
(Site Layout/Design and Constructibility Reviews)	
Midsemester Oral Presentation	10%
Status Report No. 3	10%
(Building Interior and Exterior Design)	
Status Report No. 4	10%
(Final Design, Final Cost and Time Estimates)	
Final Oral Presentation	10%
Final Project	30%
Peer Evaluations	10%
TOTAL	100%

Evaluation and Assessment

The basic starting point for assessing student learning begins with asking two basic questions: 1.) what should students know and be able to do at the end of the semester?, and 2.) what evidence will indicate that they have reached these goals? (2). The basic tools that were used for assessing knowledge in the capstone course were the status reports, the oral presentations, and the final projects. For the capstone course, evaluation of the student work (status reports, oral evaluations, and the final project) was performed by faculty teams who had expertise in given areas (structures, geotechnical, cost estimates, schedules, etc.). Grading criteria was developed for each status report, the oral evaluations, and the final project. Appendix A (4) contains the form used to evaluate the oral presentations. Appendix B contains the evaluation form used to evaluate team members. The actual deliverables and the grading criteria for the status reports and the final project were developed in class by the student groups, with input from the faculty. The faculty members that graded each of the status reports and final project used the formatted versions of the student-based deliverables for their evaluation of student work. Appendix C illustrates the grading sheet that was used for Status Report No. 1 (Work Plan, Cost Estimate, and Project Schedule). Student-based course assessment was performed twice during the semester, at the midsemester point and at the end of the semester. The final course evaluation form is found in Appendix C. Since the course, in its present format, was offered during the Fall 2001 semester, the results of the student evaluations have not been compiled. A summary report will be developed that documents the information collected from evaluating student work, the positive and negative aspects of using student-based deliverables, and overall course assessment. This work will be completed during the Spring 2002 semester and will be distributed to faculty for the purpose of revising and improving future capstone course offerings. This information is not currently available for publication, but will be presented at the ASEE Annual Conference and Exposition in June 2002.

Benefits

The primary benefits of the PBL approach for the capstone experience are that it, 1) more realistically reflects actual design and construction practices, 2) promotes the concept of teamwork, and 3) assists in improving student communication skills. For our capstone course, construction management students increase their exposure to design activities, while civil (and construction engineering) students increase (or supplement) their knowledge in the area of project management and in the long run may mitigate the adversary relationships that often occur between contractors and engineers.

Bibliography

- 1 Allen, D., Introduction to Problem-Based Learning (PBL), a workshop organized by the Faculty Institute for Excellence in Learning, August 21, 2001.
- 2 Duch, B., Groh, S., and Allen, D., The Power of Problem-Based Learning - A Practical "How To" for Teaching Undergraduate Courses in Any Discipline, Stylus Pub., April 2001.
- 3 Rhem, J., Problem Based Learning: An Introduction, a featured article in the National Teaching and Learning Forum, Vol. 8, No. 1, 1998
- 4 Kaufman, D., Felder, R., and Fuller, H., Accounting for Individual Effort in Cooperative Learning Teams, ASEE Journal of Engineering Education, pp. 133-140, April 2000.

Biography

Charles McIntyre is an Assistant Professor in the Department of Civil Engineering and Construction at North Dakota State University. Dr. McIntyre is a advanced FIEL fellow and has developed several faculty seminars dedicated to enhancing student learning. He attended the PBL workshop at the University of Delaware and has worked on implementing PBL into his course offerings. Dr. McIntyre has received several awards and university recognition for teaching efforts.

Appendix A

Reviewer:

Fall Semester 2001

EVALUATION OF THE ORAL PRESENTATION

**CE 489: Senior Design, CME 413: Construction Capstone, &
CME 489: Construction Design**

Group No.: _____ Start: _____ Finish: _____ Total Time: _____

Introductions

group members and organization (company / firm)
(Who are you and what do you do? Give a brief introduction of your firm. What is the background & specialty area of each member of the project team?)

Presentation of Alternatives (Conceptual Plans)

a brief description of each alternative
the anticipated / estimated project start date and completion date
interim project milestones
anticipated / estimated total project cost
positive and negative aspects of each plan (advantages/disadvantages)

Selection of the Preferred Plan

explanation of the criteria used to select the preferred alternative
justification of the selected alternative

Response to Questions

General Comments

organization of the presentation
clarity of the visual material
overall quality of the presentation
did you read from your notes?
did you read from the slides?
did you address the audience?
were you prepared?

Overall Rating: _____

(1 = poor, 2 = adequate, 3 = average, 4 = very good, 5 = outstanding)

Appendix B

Fall Semester 2001

CE 489: Senior Design, CME 413: Construction Capstone, & CME 489: Construction Design

PEER EVALUATION OF GROUP MEMBERS

Your Name: _____ Group No. _____

Please write the name of all of your other group members (do not include yourself) and rate the degree to which each member fulfilled his/her responsibilities in completing the assigned tasks. The possible ratings are as follows:

Excellent	Consistently went above and beyond -- tutored teammates, carried more than his/her fair share of the load
Very Good	Consistently did what he/she was supposed to do, very well prepared and cooperative
Satisfactory	Usually did what he/she was supposed to do, acceptably prepared and cooperative
Ordinary	Often did what he/she was supposed to do, minimally prepared and cooperative
Marginal	Sometimes failed to show up or complete the assigned tasks, rarely prepared
Deficient	Often failed to show up or complete the assigned tasks, rarely prepared
Unsatisfactory	Consistently failed to show up or complete the assigned tasks, unprepared
Superficial	Practically no participation
No Show	No participation at all

These ratings should reflect each individual's level of participation, effort, and sense of responsibility, not his/her academic ability.

Name of Group Member	Rating
_____	_____
_____	_____
_____	_____

Your Signature: _____

Appendix C

Fall Semester 2001

CE 489: Senior Design, CME 413: Construction Capstone, & CME 489: Construction Design

Status Report No. 1 Work Plan, Cost Estimate, and Project Schedule

Introduction (5 pts)____
Who are you? What do you do? What is your background?

Project Objectives (5 pts)____
What are you going to do? How are you going to do it?
How long is it going to take? How are you going to measure the progress?
What are the project costs?

Plan of Work and Work Breakdown Structure (10 pts)____
Detailed description of your work plan. WBS with code numbers.

Constructibility Review (10 pts)____
(site conditions and restrictions; sequence of work as planned;
proper allowances for space and access; coverage, clarity, and
consistency of specifications; lead-time requirements; economic
aspects; & quality construction and safe working conditions)

Cost Estimate (40 pts)____
QTO and costs for all resources (labor, equipment, & material)
Computerized version of the cost estimate

Project Schedule (30 pts)____
Summary Table of Scheduling Information
Computer Generated Project Schedule
(all project activities from the Summary Table, computerized
version of the schedule, showing the critical path and WBS, tabular
or graphic resource report)

TOTAL (100 pts) _____

Appendix D

Fall Semester 2001

CE 489: Senior Design, CME 413: Construction Capstone, & CME 489: Construction Design

COURSE EVALUATION FORM

At the conclusion of this semester, please answer the following questions. *If necessary, use the back side of this sheet for any additional comments.*

1. On a scale of 1 to 10, how would you rate your overall experience in working with your group? _____.

Please explain:

2. Overall, how would you assess or rate the work that your group did? (Was it your best effort? Could you have done better? Were you happy with your work? Did you have serious time constraints? Were the objectives of the course unclear?)

3. Were faculty consultants response to technical questions helpful in attaining solutions?

Please explain:

4. Did you like the way in which class meeting time was used?

If not, how would you suggest that class time be used?

5. What did you like best about this course?

6. What did you like least about this course?

7. Overall, what did you think of the course and what suggestions (general or specific) do you have for improving the course?