Engaging Students' Creativity and Interest Early Through a Freshman Civil Engineering Design Course

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***Abstract* - This paper describes how a real world design project was brought to a freshman level course to engage students in a practical civil engineering design project using simplified design approaches. By introducing the intriguing project to freshman, students are driven early in their academic career to pursue an engineering profession. The Freshman Design course is a critical part of the Civil Engineering program at California State University at Los Angeles (CSULA) and provides valuable hands-on learning and research experience to students. In 2012-2013, the students were required to perform a preliminary design of a new water conveyance system and support facilities, including a dam, pump station, and pipeline that supplies water to a local Southern California community. With guidance from the faculty, students were able to engage in gathering project data, develop design alternatives, apply technical and non- technical design constraints, analyze alternatives through pros and cons comparisons, and recommend a preferred solution. A challenging parameter of the design project consisted of a pipeline that crossed an earthquake fault, which required students to address fault-crossing design of pipelines. They also participated in a seismic research program where the performance of a ductile iron pipe was tested to simulate earthquake displacements and loads that lead to pipeline failure in shear and bending. The project deliverables include layout drawings of the dam, pump station, and pipeline, the application of the design constraints of the project, and analysis of alternative pipeline alignments. With this course, the students learn early-on applications of ABET design constraints pertaining to economic, social, political, environmental, sustainability and ethical elements. The students made PowerPoint presentations of their reports to industry professionals who evaluated their work. The assessment shows that students developed creative thinking skills, practical design skills and interest in civil engineering early on in their studies at CSULA. This course has been the foundation of a strong civil engineering design program that has received two national awards for our senior design projects on connecting professional practice with education.**

Index Terms – Freshman Design, Creativity, Engaging Students, Design constraints

THE PROBLEM:

Research done by Edgar Dale [1] has shown that the effectiveness of learning or the learning retention rate from a "lecture" is 5%, however that retention rate increases to 75% in a "practice by doing environment" and up to 90% in an environment where "immediate application of learning in a real situation" is encouraged. This was evident in the freshman design class at CSULA where students were attempting to learn the principles of Civil Engineering Design which includes topographic mapping, plan and profiles, cross sections, and other technical and non-technical aspects of civil engineering design.

THE CHALLENGE:

It is well documented that many educators have used design projects throughout the engineering curriculum [2]. One of the examples is the capstone design experience at senior level [3]. Our challenge is to introduce civil engineering design principles in a freshman civil engineering design course that provides valuable learning and research experience, introduces the essence and various disciplines of Civil Engineering, provides basic knowledge of Civil Engineering Design to help students to understand fundamental engineering concepts, and encourages the development of critical thinking and problem solving skills. The goal is to provide an engaging class setting where the student's learning experience can be enhanced.

THE AAPPROACH:

The solution approach is to create a project-based learning environment where students can learn in an interactive manner that challenges them to find a solution to a real-world problem. This would allow students to explore the problems by themselves, to make genuine mistakes and learn from mistakes, and collaboratively learn and solve problems in a team environment.

CLASSROOM STRUCTURE:

The Freshman Civil Engineering design class meets four hours a day, twice a week for ten weeks in a quarter system. It has two hours of lecture and six hours of design lab. The course has prerequisites of Plane Surveying, Introduction to CAD and Physics I. With this background, students are introduced to a practical civil engineering project where they can use basic knowledge to gain engineering design skills. The engineering design process [4] was presented in the following steps:

a) Define the problem
b) Gather pertinent information
c) Develop alternative solutions
d) Apply design constraints
e) Analyze each alternative using engineering skills and design constraints
f) Recommend the best solution

In this process students have to engage in an iterative process of design to come up with a best solution.

a) Define the problem: In 2012-2013, the students were required to perform preliminary design of a new water conveyance system and support facilities, including a dam, pump station, and pipeline that supply water to a local community adjacent to the City of Corona. The project required the design of a one-mile long pipeline that crosses an earthquake fault from a pump station at a base of a dam to a storage facility at a hilltop. Students were required to determine reservoir storage capacity, location, dam configuration and pipeline alignment based on the given constraints.

b) Gather pertinent information: The students were given a topographic map of the region. The students then researched applicable technical constraints such as site conditions and local geology as well as non-technical constraints. These constraints were then incorporated in their project design.

c) Develop Alternative solutions

Each student team developed four alternative routes for the dam and pipeline complete with plans, profiles and cross sections. They later used these profiles and cross sections to determine the best alternative based on design constraints.

d) Application of Design Constraints: With this project, the students learned early-on applications of ABET [5] design constraints such as economic, social, political, environmental, sustainability and ethics in addition to the technical Civil Engineering design criteria and methodologies. They then critically evaluated each alternative under these constraints.

e) Recommendation of best alternative:

Once the student teams analyze the alternatives with design constraints, they present the alternatives and defend it in an oral presentation before a panel of professional engineers and industry affiliates . The teams list the advantages and disadvantages of the proposed solution and a cost estimate for construction.

Each class session began with specific topics to be applied in project design. The topics are summarized as follows:

1. Civil Engineering in today's world
2. Civil Engineering Specialty Fields
3. The Design Process
4. Contour Lines
5. Topographic Maps
6. Topographic Surveying
7. Introduction to water demand analysis
8. Introduction to water storage reservoir design
9. Horizontal and Vertical Alignments
10. Longitudinal Profiles
11. Cross Sections
12. Area and Volumes
13. Site Investigations
14. Design Constraints (Technical and non-technical)
15. Introduction to Project Management
16. Quantity Take-offs and Cost Estimating
17. Introduction to Written Specifications
18. Introduction to Earthquake fault crossings

The students will be required to implement elements of the above topics in project preliminary design. The drawings are prepared using MicroStation [6] CAD software. Samples from the student projects are shown in Figures 1, 2, and 3.

During the design process, students are encouraged to share gained experience that resulted from errors and mistakes. Mistakes provide an opportunity for the class to discuss and learn from each other. Recognizing the mistakes can effectively and positively reinforces engineering concepts. By reducing the number and time devoted to lectures and increasing the interactive problem based learning in a team environment, students learn better by applying engineering concepts to solve a practical problem. In order to provide students with exposure to academic research, they also participated in a seismic testing program where the performance of a ductile iron pipe was tested in the lab to simulate earthquake loads that lead to shear and bending failures.

The course included a final group project report and a presentation before a panel of professional engineers and industry representatives.

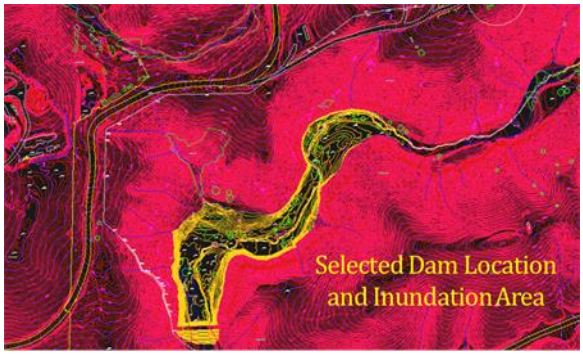


Figure 1: A student developed dam location

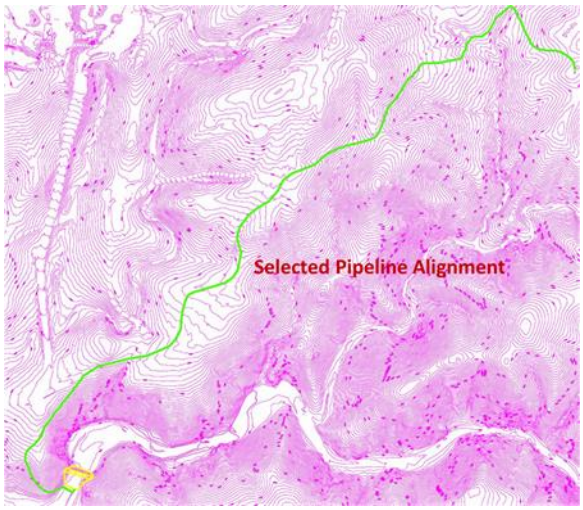


Figure 2: A student developed pipe line alignment

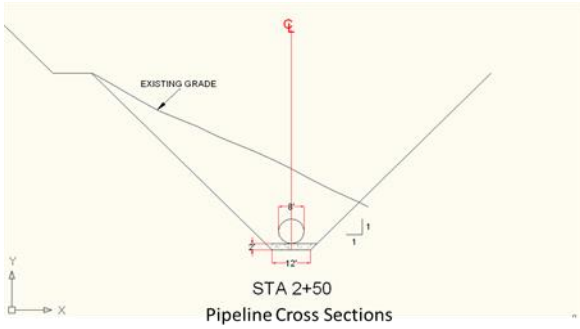


Figure 3: A student developed pipe line cross-section

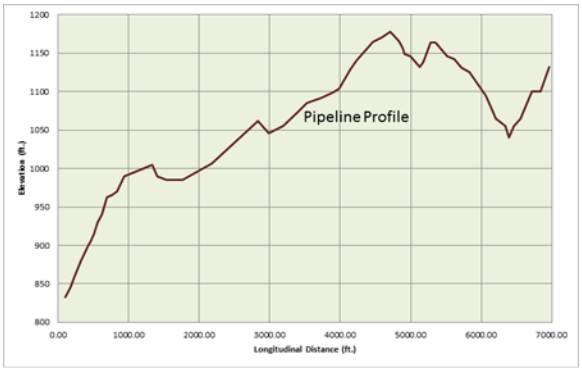


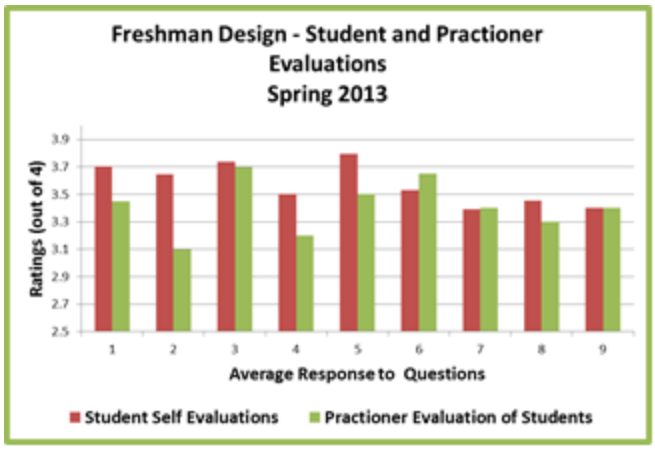
Figure 4: A student developed pipe line profile

The students are graded based on class attendance, project participation, teamwork, quizzes, a final examination, group project reports and PowerPoint presentations. The individual quizzes and exams are based on lecture materials and design skills learned for the project.

COURSE ASSESSMENT

The course assessment comprises of: i) self-assessment by the students ii) student oral report assessments by industry representatives. A summary of partial student self-evaluations and practitioner evaluations are documented below. The ratings are based on thirty-four students and four practitioner responses with a zero-to-four scale (4 being the highest with 100% satisfaction). Based on this survey the students successfully gained design skills, gained creativity, understood the civil engineering profession, attained positive teamwork with fellow students and more importantly wanted to continue their studies in civil engineering beyond freshman years.

QUESTIONS	NUMBER
How well has this design course helped to plan and design components of a civil engineering project? (Abet c)	1
How well has this design course helped in the understanding of professional and ethical responsibility?	2
How well has this design course helped to enhance understanding of the Civil Engineering Profession?	3
How well has this design course helped to enhance knowledge of the various civil engineering fields?	4
How well has this design course helped to enhance students' desire to continue with studies in the field of civil engineering?	5
How well has this design course helped to develop student creativity as it pertains to civil engineering profession?	6
How well has this design course helped to develop camaraderie relationships of fellow civil engineering students?	7
How well has this design course helped to enhance the understanding of working in teams?	8
How well has this design course helped to get a part time civil engineering related internship while in school?	9



Both the students and practitioners are in great agreement (ratings greater than 3.5/4.0) that the freshman design project has helped the students to understand the civil engineering profession, motivate them to continue civil engineering studies, and develop creativity through open ended design project early on in their engineering study. While the students thought they understood the ethical aspects, professional aspects, and various topics in civil engineering very well, the practitioners gave a somewhat low rating. However all the scores were above 3.0 out of 4.0.

CONCLUSIONS:

Students have a lower tendency to retain the facts that they have heard in a lecture, but show a positive understanding of the concepts by working hands-on and applying knowledge through actual practice. Working in teams encourages peer learning and allows for the flow of ideas between students, which helps them to learn better, correct their mistakes and provide a better solution. This course allows freshmen students to identify individual interests within the field of civil engineering, which will guide them to pursue a specialization later on. After this course, they have a better understanding of project design process, teamwork, application of basic engineering knowledge, communication skills and critical thinking required for academic success in the Civil Engineering program.

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