AC 2007-1395: OPEN-ENDED DESIGN PROJECT AS INTRODUCTION TO DESIGN FOR CIVIL ENGINEERING FRESHMEN

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Open-Ended Design Project as Introduction to Design for Civil Engineering Freshmen.

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Abstract

A freshman design course - CEGR 105 Introduction to Civil Engineering - was designed and delivered as part of the effort for 'early introduction of design into the engineering curriculum'. The course is a second semester orientation course that follows a broader first semester course called ORIE 104 Orientation to Engineering.

With a team-teaching approach, members of the civil engineering faculty with varied technical backgrounds taught the class and assisted with various aspects of the design project. All lectures were focused on supporting the design project, which varied from alternative energy systems to hurricane resistant structures. The required class was primarily composed of freshmen in the Department of Civil Engineering. Typical student teams consisted of 5-6 members. Student teams were guided to follow the process of translating project objectives into specific design tasks, creating a timeline for the project, choosing team leadership, designating specific roles within the team and executing the design. The teams were also encouraged to establish a formal project monitoring system by defining a schedule of benchmark objectives. The 1 credit course, a with a total meeting time of 30 hours over a 15-week semester, consisted of approximately 10-12 hours in class dedicated to the design project, with an additional 4-6 hours in various forms of reporting. Teams were required to submit a written proposal and a final report, as well as make a formal team presentation of their design.

A very detailed course assessment tool was used to obtain student feedback at the conclusion of the exercise. This (assessment) included self and peer assessment by the students in reference to the team design project. Students were also asked to provide detailed feedback about the quality and relevance of lectures and the quality of instructions and specifications about the project.

In accordance with ABET 2000 criteria, the student feedback was analyzed, the results of the formal analysis being the basis for a system of continuous improvement to the course delivery.

Introduction

Multiple reports point to the decline in recruitment and retention of students studying science, technology, engineering and mathematics (STEM) as well as the increase in the rate of professionals leaving STEM (NSB, 2003; NSB, 2004). The Task Force on American Innovation reports that the number of jobs openings in STEM areas is five times the number of US students graduating in STEM. The National Science Foundation's (NSF) "Strategic Plan: FY 2003-2008" acknowledges that tapping the potential in "previously underutilized groups" will be critical for sustaining the technological lead the U.S. enjoys throughout the world (NSF, 2006). National concern has been expressed about the status of the U. S. science and engineering base-specifically the human talent, knowledge and infrastructure that generate innovations and undergird technological advances to achieve national objectives. Analyses have shown that there may be a significant shortage in the entry level science and engineering labor pool, and that scientific and technical fields could be significantly affected. Demographic data also shows a future with proportionately fewer young people and a work force comprised of growing numbers of minorities and the economically disadvantaged. These groups, which the economy must increasingly rely, have been historically underrepresented in science, engineering and related fields.

According to Nikias, the Dean of the Viterbi School Engineering at University of Southern California, we have forgotten why these students wanted to become engineers in the first place. Engineering is enormously creative. If science is all about understanding nature, then engineering is about applying that understanding to create new technologies that profoundly affect our lives. But the traditional approach to engineering education–a heavy dose of rigorous math and science during freshman and sophomore years–does not engage students' vision of an engineering career. Freshmen students are suddenly confronted with classes that seem to have little relevance to the discipline. Mathematics faculty members, rather than those in engineering, usually teach math classes (Nikias, 2005). The freshman year for an engineering student is very critical to his or her retention in the in the engineering program. There are reports in literature that the introduction of design in the freshman engineering course has an impact on the retention of students in engineering program , stimulated interest in engineering among freshmen, enhance soft skills like communication, working in teams and time management (Karl et al., 2000; Parker and Anderson, 2004; Rowe & Mahadevan-Jansen, 2004). One of the ways of retaining and stimulating students in engineering is therefore to involve them in engineering projects early in the program. Morgan State University School of Engineering under the auspices of Curriculum Development activities of ECSEL (Engineering Coalition of Schools for Excellence in Education and Leadership), a cross-institution coalition of universities including City College of New York, Massachusetts Institute of Technology, Penn State University, Howard University, University of Maryland and the University of Washington submitted a proposal to address this issue to the National Science Foundation and was funded in October 1990.

The course CEGR 105 – Introduction to Civil Engineering was first developed by Goswami and Sincero as part of the Year 1-5 activities of this grant at Morgan State University. The course's basic premise was to introduce engineering design to Civil Engineering freshmen. The course was offered for the first time in 1994. For the first two years (1994, 1995), the course was taught by Goswami and Sincero. According to the university catalog the description of the course is:

"This orientation course will introduce students to the concept of engineering design by exposure to several design problems from various areas of civil engineering including: structural, transportation and environmental engineering". It is a one unit course which meets for one hour forty minutes per week offered in the spring semester. The objectives of the course are (a) to introduce the students to all of the main sub-areas of civil engineering, and (b) have students work in teams to accomplish the design of a civil engineering project, while supplying them with some of the supporting theory, to be used virtually as a 'black box', since it was too early in the curriculum for them to have experienced these topics firsthand. After a couple of years, it was decided by the faculty that whereas this approach had some merit, it would be far more useful to give students a sense of the *design process*. Prior to spring 2002 this course was taught by individual faculty to a section of students. This in effect meant that those students were only exposed to the area of concentration of the particular faculty. In some semesters other faculty with different expertise might be invited as guest lectures to the class. In order to expose all the students to all the areas of concentration of civil engineering, all the faculty assigned to teach this course (Davy, Li, Oguntimein, Oluokun and Sincero) met and decided to team teach the course combining all sections of the course.

Basic syllabus of the course

This course is offered once a week, the class time split into two 50-minute halves separated by a 10-minute break. Table 1 outlines the syllabus for the course, which is offered during the spring semester. Typically, the first fifty minute of the class is a lecture on one of the subspecialties of Civil Engineering, delivered either by the appropriate faculty member or an invited speaker. The second fifty minute of the class allows students to break out into groups, to continuously develop specific details of their design project.

Table 1. Course Outline and Schedule.

	First Hour	Second hour
1	Introductions. ASCE video. Ethics and liability	Design-Build, Bid Process, Project groups
2	Planning & Design Process	Project introduction, Timelines
3	Analysis & Design Tools-Spreadsheet useage	Problem Definition & Formulation
4	Structure Lecture 1	Computer Simulation & Programming
5	Geotechnical Lecture 1	Design Evaluation & Modification
6	Environmental Lecture 1	Design Evaluation & Modification
7	Transportation Lecture 1	Preliminary Design Due
8	Water Resources Lecture 1	Detailed Design (supervised)
9	Structure Lecture 2	Detailed Design (supervised)
10	Geotechnical lecture 2	Detailed Design (supervised)
11	Environmental Lecture 2	Detailed Design (supervised)
12	Transportation Lecture 2	Detailed Design (supervised)
13	Water resources lecture 2	Draft Design Report Submittal
14	Final Project presentation	
15	Final Design report Submittal	

Design Projects

The faculty meets during the winter break to decide on the project that the students are going to work on in the spring semester. The students are divided into teams of approximately 5-6 students. The team assignments are made randomly by the faculty on the first day of class. The design problem is presented to the students in the second week of the semester. Table 2 lists some of the projects that have been worked on over the years. These projects are usually open-ended problems of relevance to the society. The students work on these projects as a team using some techniques of project management and in the process learn how to work in a team environment.

In the spring 2001 the project was to design an electricity generating plant that uses ocean tides as the source of energy. The site is to be along the United States coastline with the following considerations: difference in elevation between high and low tides, availability of land adjacent, profile of adjacent and submerged land and environmental concerns. The plant should have devices to convert energy from tides to electricity and the following characteristics should be taken into consideration, selection of sizes and materials, evaluation of strength of materials, anchorage of components, durability, improving efficiency, procurement, and cost.

Table 2. List of Projects worked on in CEGR 105.

Semester	Title of project
2001	Design a plant that uses ocean tides to generate electricity.
2002	Design of a water treatment plant in the ocean using Osmotic pressure system.
2003	Design of a mass transit system for Baltimore City
2004	Design a structure to serve as a laboratory on the Martian surface
2005	Design a feature in a structure that allows the structure to respond automatically to a disturbance (earthquake, wind, tsunami, etc) so as to minimize damage to the structure.
2006	Design a system to protect a metropolitan area on the US coastline along the Gulf of Mexico from a Category 4 hurricane.

In the spring of 2002, the project was to design a water treatment plant in the ocean using osmotic pressure system. The population of the community to be served was given. The students were asked to be aware of certain limitations such as the rigidity of the structure in an ocean environment.

In the spring of 2003 the project was to design a mass transit system for Baltimore city.

For the spring of 2004, the assignment was to design a structure to serve as a laboratory on Mars. Some specifications were – occupancy, specific usage designations for the structure, payload restrictions (weight and volume), and limitations on size of individual parts. Students were asked to pay attention to the following issues while identifying preliminary design concepts – portability, constructability, durability, modular nature, waste disposal, minimizing environmental impact, use of local resources, energy requirements. Students were asked to be aware of certain practical limitations, such as – connections must be such that they don't require dexterity, structure must have small mass for good maneuverability, knowledge about Martian surface must be used to design foundations.

For the spring of 2005 the students were asked to design a feature in a structure that allows the structure to respond automatically to a disturbance (earthquake, wind, tsunami, etc) so as to minimize damage to the structure. The following aspects were to be considered in the design the type of structure which could be a building (home, office, hotel, school, etc), bridge (steel, concrete or composite; slab-stringer, truss, arch or cable-stayed; etc), transmission tower, offshore platform, etc. The structure should be able to withstand exposure to the disturbance over a 100-year period. They were free to define the disturbance, root cause of disturbance, how it propagates, how is it measured, it's effect on the structure. The design is to minimize the effect of the disturbance, showing how this can be accomplished, possible devices – sensors, actuators, dampers, etc. and how the devices can be incorporated and activated. Design of damage-reducing component, choosing system and components, selection of sizes and materials, verifying that the system will work, durability, efficiency, maintenance and cost of the system.

In the spring of 2006 the project was to design a system to protect a metropolitan area on the US coastline along the Gulf of Mexico (Pensacola, Florida metropolitan area and Galveston, Texas metropolitan area) from a Category 4 hurricane. The following (minimal) aspects were to be considered in the design, Category 4 hurricane, definition, historical record in Gulf – wind speed, rainfall, storm surge, flooding, etc., loss of life, damage to property, cost, and recovery time, characteristics of metropolitan area under consideration, population, demographics, topography, vulnerability, protection system in place. Design of protection system, warning system, evacuation plan, protection from wind, protection from flooding, storm surge (main focus), city, state, federal coordination/management plan, restoration of infrastructure – water supply, electricity, food supply, etc., repopulation and cost.

The deliverables expected from the students are: - All plans must be drawn using AutoCAD 2000 or higher. Plans must include general notes and specifications. All drawings must be labeled with intended use and dimensions. All reports must be prepared using a word processor such as Microsoft Word or similar. All presentations must be prepared using Microsoft PowerPoint or similar.

Sources of information available to the students are MSU Soper Library, The Internet, The Johns Hopkins Engineering Library, Towson University Library, University of Maryland, Baltimore Campus Engineering Library, University of Maryland, College Park Engineering Library, MSU Civil and Electrical Engineering Professors.

The design process

The engineering design process was presented to the students in a lecture in the second week of the semester. The necessary steps to accomplish an engineering design - a) identification of the problem, b) gathering needed information, c) brainstorming for creative solutions, d) initial modeling and preliminary designs, e) selection of preferred solution f) detailed design for the solution and g) preparation of reports, plans and specifications - were explained and an assignment was given to reinforce the concepts. It then became the responsibility of each group to implement the process relative to the project assigned for the semester.

For each second-hour group design session, a minimum of two faculty members were present. The role of the faculty was to answer any questions raised by the students and to serve as a resource center. In order to keep the project open-ended, faculty were required not to guide the students to any particular solution to the problem. Typically each week, the group members discussed the problem, identified action items and assigned tasks to individual members. They were required to maintain a log of their activities. A report on each task was expected to be presented to the group at the following week's session and used to advance the project. The interim and final written reports were assembled through tasks assigned to the group members.

The importance of using engineering graphics in the presentation of their ideas and designs were emphasized early in the semester. Since most students would have taken CEGR201 – Introduction to Computer-aided Engineering Graphics in their freshman first semester, there was sufficient knowledge within each group to use available graphics software to satisfy this requirement. The department's current choice of engineering graphics software is Autodesk's AutoCAD.

Assessment

During the project each team submitted a pre-proposal, a pre-design, a detailed design and a final project report for evaluation. The final reports (one per group) are submitted in week 13 (first draft) and week 15 (final). Student were given homework assignments by each faculty and graded. With respect to the project each group kept a log book. The project manager position was rotated each week so that each member had an experience as a project leader. In week 14, each team was asked to make an oral presentation of 15-minute duration, followed by a question period lasting 5-10 minutes. Participation from ALL team members was encouraged.

The student presentations were formally evaluated using a scheme that assigned scores of 0-5 in seven categories – Definition of Objectives (A), Design Content (B), Quality of Visual Aids (c), Quality of Oral Presentation (D), Methodology (E), Handling of Questions (F) and Achievement of Stated Objectives (G).

0 – Unacceptable
1 – Poor
2 – Fair
3 – Average
4 – Good
5 – Excellent

A summary of scores for each of the 5 groups is shown in Table 3. Each of the scores is on a 0-5 scale and the TOTAL SCORE is out of 35.

Table 3. An Example of the Matrix of Scores of Team Presentations

	Gr.1	Gr.2	Gr.3	Gr.4	Gr.5
A	3	4	3	4	4
B	2	4	2	3	5
C	4	5	2	3	5
D	3	5	3	3	5
E	2	4	2	3	5
F	2	4	2	3	4
G	2	4	1	3	4
	18	**30**	**15**	**22**	**32**

The grade for the project, is based on the grades for the project report and presentation. Each member of the team grades other members including themselves on their participation in the project qualitatively as shown in Table 4. Each member's final project grade is product of the weighting factor and the groups project grade. The weighed factor is calculated as shown in Table 5.

Table 4. Peer Rating of Team Members

Name____________________________________ **Project Group** _________

Please write the names of all of your team members, INCLUDING YOURSELF, and rate the degree to which each member fulfilled his/her responsibilities in completing the project assignments. 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 assignments, rarely prepared
Deficient	Often failed to show up or complete assignments, rarely prepared
Unsatisfactory	Consistently failed to show up or complete assignments, unprepared
Superficial	Practically no participation
No show	No participation at all

Reference: R.M. Felder, 1998.

The qualitative grades are assigned numerical values (Excellent = 100, Very good =95, Satisfactory = 87.5, Ordinary =75, Marginal=62.5, Deficient=50, Unsatisfactory= 40, Superficial =25, No Show =12.5) The average was divided by the group 's average to get the grade weighting factor. An example is shown in Table 5.

Table 5. Calculation of Weighting factor

Team 3									**Weighting factor**
Student1	87.5	100	100	100	100	75	100	94.64286	1.163009
Student2	87.5	87.5	87.5	87.5	62.5	75	75	80.35714	0.987461
Student3	87.5	87.5	87.5	87.5	62.5	75	62.5	78.57143	0.965517
Student4	87.5	87.5	87.5	87.5	62.5	62.5	50	75	0.92163
Student5	87.5	87.5	87.5	87.5	62.5	75	75	80.35714	0.987461
Student6	87.5	100	100	100	75	75	87.5	89.28571	1.097179
Student7	87.5	75	87.5	87.5	50	62.5	50	71.42857	0.877743
Group average score								81.37755	

Student feedback

One week after the presentations, students were asked to rate the overall experience, the perceived usefulness of the design experience, their overall performance and their peers' overall performance.
A detailed questionnaire with the following questions was given to students at the conclusion of the semester.

PART I – INSTRUCTORS
- Were the instructors punctual in arriving for the lectures?
- Were the instructors well prepared with necessary teaching materials?
- Was the instructors' manner of speaking clear and understandable?
- Did the instructors address students' questions about the project adequately?
- Were the instructors able to present a clear picture of the relevance of the project within the field of CIVIL ENGINEERING?
- Were the instructors available for students and if so, were they fair, helpful and encouraging to the students?

PART II – SUPPORTING MATERIALS (NOTES / HANDBOOKS etc.)
- Was the textbook an adequate reference to support the project?
- Were any additional materials provided useful in supporting the project?

- Did you receive clear guidance about what additional references would be needed for successful completion of the project?

PART III – COURSE CONTENT

- Was the project topic interesting?

- Was the time assigned for the project too much / adequate / too little? Realize that TIME AVAILABLE to do a job is often one of the primary constraints for it.
- Did the lectures help in supporting the design project?
- Do you have any specific suggestions about the project experience, for future offerings of the course?

PART IV – FACILITIES

- Were the rooms adequate for the class size and group activities?
- Was there anything you would prefer to have changed about the mode of the course (for example, using more or less POWERPOINT lectures or more or less of using a BOARD?

PART V – TEAM DYNAMICS

- Outside class, how much time did YOU devote towards studying per week for CEGR105?
- Outside class, how much time did your TEAM devote towards team meetings etc?
- How well did your group function in self-monitoring, accomplishment of tasks etc?

Summary of student responses

In keeping with guidelines of ABET 2000, a feedback loop was devised to assimilate and react to the student feedback. The following is a summary of some key points in the student feedback.

- One suggestion has been to 'chop up' the design project into separate, but related parts, thus giving each group time to pursue their design objectives to greater depth.
- Assignment of group members must acknowledge certain key skills, such as AutoCAD, so that the playing field is level.
- The lectures must be made more relevant to the project – maybe, the first lecture in each area talks about the practice area in general terms, while the second directly addresses relevant issues in the project.
- Groups where the workload was not shared equally suggested that there be a means to first, facilitate group dynamics, and second, to clearly indicate a method by which grade will be assigned in proportion to effort.
- Some felt that enforcing more deadlines along the way would facilitate successful completion of the project.
- Several thought that the project needed more definition from the faculty, instead of leaving parameters vague.
- There was a suggestion to assign one faculty member to each group, to serve as 'client rep'.

- The choice of text didn't seem to resonate with many. Most indicated that they had not read the text or found it irrelevant.
- There must be more uniformity in answering questions that students ask. They seemed to feel they got wildly different responses to the same question asked of two professors.

The comments made by students have been taken into consideration in subsequent years and the dynamics of the course is continuously being modified.

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