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A Hands-on Approach to Teaching Civil Engineering Technology Design Courses: A Case Study

Maher M. Murad
Department of Civil Engineering Technology
University of Pittsburgh at Johnstown
murad@pitt.edu

Abstract

This paper describes the pedagogical aspects of developing and teaching civil engineering technology design courses using a hands-on approach and the positive impact this has on student learning. The Highway Surveying and Design was selected as a case study. The elective course is offered at the senior level in the Civil Engineering Technology (CET) at the University of Pittsburgh at Johnstown (UPJ). The course develops students' ability to use mathematical formulas, design guidelines, assumptions and common sense to recommend design solutions for a highway project. The lab component of the course has been developed and fully integrated into the course through a semester long project involving the design of a road. The semester long project allows students to get hands-on experience in designing a road in a step-by-step approach. The design requirements are mixed between being open-ended and specific in order to allow members of each team to search for feasible solutions. Students are challenged to think and search for answers but yet given sources of information that will help them find such answers. Students are also encouraged to think about the logic behind their choices.

The course learning outcomes are presented and linked to accreditation criteria. Feedback from students is analyzed and discussed. The experience gained may provide useful guidance to those considering ways to develop and teach an enhanced design course in civil engineering technology that meets industry demands as well as accreditation criteria.

Introduction

The University of Pittsburgh at Johnstown offers a 4-year B.S. degree in Civil Engineering Technology (CET). The program has five areas of concentration: Construction, Environmental, Management, Structural / Foundation, and Transportation. The curriculum of at least one of the concentration areas must be completed in order for a student to graduate from the program. The current curriculum for students electing to concentrate on Transportation includes three required courses: Elementary Surveying, Civil Computations (computer applications of surveying), and Transportation. In addition, students focusing on transportation are expected to take two more courses offered to students as technical electives: Highway Surveying and Design and Pavement Design and Management. A CET graduate with concentration in the area of transportation is likely to be involved in one or more of the five major areas: planning, design (geometric and pavement), construction, operation, and maintenance of transportation facilities.

Highway Surveying and Design is an elective course at the senior level. Only Civil Engineering Technology (CET) students take the Highway Design course and it is preceded by two junior level courses in transportation. The course is design and problem solving in nature.

Accreditation Board for Engineering and Technology (ABET) outlines Civil Engineering Technology Program Criteria for accreditation [1] as follows: ABET general criterion: An ET program must demonstrate that graduates have:

- an appropriate mastery of the knowledge, techniques, skills and modern tools of their disciplines (criterion **a**).
- an ability to conduct, analyze and interpret experiments and apply experimental results to improve processes (criterion **c**).
- an ability to function effectively on teams (criterion **e**).
- an ability to identify, analyze and solve technical problems (criterion **f**),
- an ability to communicate effectively (criterion **g**),
- a recognition of the need for, and an ability to engage in lifelong learning (criterion **h**),
- an ability to understand professional, ethical and social responsibilities (criterion **i**),
- a respect for diversity and a knowledge of contemporary professional, societal and global issues (criterion **j**).

In addition, CET program specific requirements that the course should be meeting include that graduates be capable of:

- employing productivity software to solve technical problems (criterion **f**).
- applying basic technical concepts to the solution of civil problems involving hydraulics, hydrology, geotechnics, structures, material behavior, <u>transportation systems</u>, and water and wastewater systems (**d**).
- performing standard analysis and design in at least three of the recognized technical specialties within civil engineering technology that are appropriate to the goals of the program (**e**).

The CET program as a whole is expected to meet the above criteria with contribution from the different courses offered. A closer look at the ABET criteria indicate the important role upper level courses can play in satisfying the criteria. The Highway Surveying and Design course has been designed so that ABET criteria is met when possible. The content of the course was based on consultation with industry through members of the engineering technology division Industry Advisory Committee (IAC). Specific measurable course outcomes have been outlined to represent what students are able to do at the end of the semester. The course syllabus outlines the course outcomes, expectations, grading system, detailed lecture and lab schedules, and reading assignments.

Class Activities

Because of the design nature of the course, the approach to class activities is as follows: the instructor outlines a design problem and the class is requested to form groups of two or three students. The instructor then asks the whole class to think about the first component of the design problem and assigns that design component to one group at random. The selected group is requested to think about the problem and discuss it among the group members. The selected group, through its representative, suggests possible solutions to that design component. The instructor then interacts with the selected group about the design suggestions and opens the discussion to the whole class for their input. Another group is then selected. The new group verifies the computations of the previous one before carrying out the next task. The process continues until the design problem is solved completely.

For assessing student learning, the author has developed and used the concept of Mixing Exam Formats (MEF) to enhance student learning beyond the exam and to train students to become more familiar with the Civil Engineering Professional Exam (PE) multiple-choice exam formats [2]. Under this concept, the instructor grades the exam such that each student gets two scores: the first is called "Objective Score" which is based only on grading the multiple choices. The second score "Traditional Score" is based on the traditional grading of the detailed solution. The instructor then returns the exams having graded the "Objective" portion. If an "Objective" answer is incorrect the students are required to thoroughly analyze their own work to determine where they made specific errors and why the correct answer was not determined. Students report their findings in a report. The instructor grades the reports and gives a final grade which is a combination of the two scores. The use of MEF concept helps students understand the material covered in the exam while also improving their test taking skills especially choosing the most correct answer. The concept allows students to identify and eliminate their mistakes. Students expressed an understanding and appreciation for the MEF concept, endorsing the additional learning opportunity provided and the training on reaching the most correct answer.

Lab Activities

The lab involves a semester long project to design a highway. Students carry out a route survey and design, in phases, both the horizontal and vertical alignments of a proposed road. Students submit a report after completing each design phase and they submit a complete final report with drawings at the end of the semester. The following are the lab activities:

- Students work in teams of three or four.
- The instructor outlines a semester long project at the beginning of the semester.
- The project is broken into tasks that can be completed in one or two weeks.
- The instructor outlines the requirements of each design assignment.
- The design requirements are mixed between being general (open-ended) and specific in order to allow members of each team to search for feasible solutions that meet the American Association of State Highway and Transportation Officials (AASHTO) or Pennsylvania Department of Transportation (PennDOT) design guidelines.
- Different teams may end up with different design solutions.
- The instructor approaches each team and discusses with the team members their design suggestions and possible alternatives.

- Students are challenged to think and search for answers but yet given sources of information that will help them find such answers.
- Students are encouraged to think about the logic behind their choices. Any suggestion should be supported by documented design guidelines or specifications and it should make sense too.

General lab objectives include successful teamwork; improving presentation and communication skills; improving writing and lab preparation skills; hands on experience on how to design a highway including utilizing a design software in the analysis and design.

Cooperative learning is used as the instruction style in the lab. Cooperative learning is defined as instruction that involves working in teams to accomplish an assigned task and produce a final product, under conditions that include the elements: *Positive Interdependence*, *Individual Accountability*, *Face-to-Face Promotive Interaction, Appropriate Use of Teamwork Skills, and Regular Self-assessment of Team Functioning* [3]. An extensive body of educational research confirmed the effectiveness of cooperative learning in higher education [4]. The term "Team" is used here and not "Group" because in teamwork, activities span for a long time (weeks, whole semester) while activities span short time frame for group work. Also, teams are formed carefully while groups are formed spontaneously [5]. The students work in teams of three or four and are carefully formed by the instructor. Academic research indicates that instructor formed teams perform better than totally self selected teams [6]. At the beginning of the semester, students are asked to fill out a student data sheet in which they provide information about their technical background and experiences inside and outside of school as well as their interests. The student data sheet provides feedback on each student's prior learning to help determine the "starting" point of instruction [7]. The student data sheet also includes information that will help the instructor in team formation.

A design software "Land Development Desktop (LDD)" is introduced to students to aid in the analysis and design of a highway facility. LDD is an AutoCAD based software, which is available among a number of other computer programs on the UPJ computer network. The software covers topics that include roadway design, hydrology, site grading, and surveying. Initially, the software was introduced as a demonstration class to illustrate the designing ability of the software, especially performing design calculations and producing project drawings. Students expressed appreciation for the software and demanded more integration of the software in the design process. The plan to integrate the LDD software into the course is presented to students on the first day of classes. The idea is discussed along with the course syllabus. The intention of using the software as a learning tool and as a way to aid in both analysis and design is also discussed.

One provision of team formation is for each student to identify a student with whom he/she would like to work and one student with whom he/she would prefer not to be teamed [8]. Students are told that their choices will be taken into consideration but are not guaranteed because of feasibility problems such as the case when many students name one student whom they wish to work with. Another consideration was that students with a background or experience in LDD or similar software are distributed over the groups such that the few students who have a good background in highway design or LDD from summer internships or part time jobs do not end up in the same team.

The LDD design software is integrated into the course through the semester long project assigned to the students at the beginning of the semester. The project is broken into tasks that can be completed in one or two weeks. The requirements of each design assignment is outlined and given to students as a handout. The students first carry out the design tasks manually to fully understand the design process then they employ the LDD software to verify their manual design. The students then use the advanced features of the software to carry out sensitivity analysis and produce different design alternatives in a relatively short time. The general sequence by which the software is integrated into the course is given in the lab schedule as part of the syllabus.

When the meeting with students is scheduled for computer applications using the LDD, students meet in the computer lab. The capacity of the lab is limited to 15 to allow for full interaction between students and instructors to ensure that students follow the instructions correctly. The use of the software is presented to students through an active session using a real design example. The presentation follows a carefully planned outline, with built-in questions and side notes to stimulate class discussions as well as to motivate students' interests. Each student is required to get access to the software and to work out a design example in a step-by-step approach along with the instructor. Students also take notes on the discussions of advanced features that may not be included in the example but could be part of their highway design project. The students get a tutorial hand out to help them perform the different tasks. They are also required to complete a reading assignment from the lab textbook, which provides a basic understanding of the tools found in Land Development Desktop and its two add-ins (Surveying and Civil Design) [9].

Grading student performance and teamwork is done such that individual accountability is considered in the grading. With each submission, students are asked to fill a sheet to report on the rating of each team member with respect to the degree to which each member has fulfilled his/her responsibilities in completing the lab assignment [6]. The Autorating System is used to assign a final grade to each team member [10].

Feedback from Students

A questionnaire was administered to obtain feedback from students on the hands on approach in teaching the Highway Surveying and Design Course, especially the lab component. The questionnaire consists of 12 questions. In 10 questions, the answer format is multiple-choice such that the range of responses is from "1" meaning "Definitely No" to "5" meaning "Definitely Yes". The highway class consists primarily of seniors. 18 students were in attendance and completed the questionnaire. Table 1 presents the student responses with respect to their opinions on the practicality of the course and the usefulness of the lab component. The percent of maximum score and average student response have been used to quantify the response by students to these questions as shown in Table 1. The maximum score is the number when all students select "Definitely Yes" which has a value of five (5) as their response in favor of the idea (i.e. maximum score = 100).

Table 1: Student Responses to questions on Integrating LDD in Highway Design

No.	Item	Response	
		% of Maximum Score (Max=100)	Average (5 for strongly agree)
Q1	The lab was a valuable component of this course.	94	4.7
Q2	There was a good coordination between the lecture and the lab.	90	4.5
Q3	Lab handouts were clear and helpful.	81	4.0
Q4	The breakdown of project activates was logical and allowed the project to be completed as scheduled.	84	4.2
Q5	The instructor encouraged students to search for answers and to state the reasons for their choices.	85	4.2
Q6	It was a good idea to include PennDOT design guidelines in addition to that of AASHTO.	94	4.7
Q7	Working in teams was challenging but important	90	4.5
Q8	Using the Land Development Software in design was a good and helpful idea.	92	4.6
Q9	Writing formal reports in this lab helped me improve my writing and my report preparation skills	86	4.3
Q10	The class and lab prepared me to be able to design a real world highway	95	4.8

The following comments can be made on Table 1:

- The majority of students (score 4.7 out of 5) indicated that the lab was a valuable component of this course. They also indicated that there was a very good coordination between the lecture and the lab.
- The instructor prepared a handout for each lab to help the students understand the requirements and procedure involved. Most students indicated that the lab handouts were clear and helpful in conducting each study. They also indicated that the breakdown of each lab activities was logical and allowed each project to be completed as scheduled.
- Most students agreed that the instructor encouraged them to search for answers and to state the reasons for their choices. Almost all students thought it was a good idea to include PennDOT and AASHTO design guidelines.
- Most students (score = 4.5) acknowledged the challenge involved in teamwork, but agreed that teamwork is vital for the successful completion of civil engineering projects. Obviously becoming a good team player is a process that would take years of practice in working in teams. This lab is a step in this direction.
- Almost all students in this class unanimously found integrating the Land Development Desktop (LDD) in the highway surveying and design course a good and helpful idea.
- With a score of 4.3, it is evident that the writing component of the lab helped students improve their writing and their report preparation skills. The lab required students to

submit formal reports in stages and a final comprehensive report at the end of the semester.

- Finally, The vast majority of students (score = 4.8) strongly agreed that the class and lab prepared them to be able to design a real world highway, the main objective of the course.

Question 11 in the questionnaire asked students to list the best things about the class and lab. Following are excerpts from the comments made by students:

- "*hands on aspects, real world experience*"
- "*was able to see how a whole project is put together from beginning to end*"
- "*working as a team, handouts were helpful"*
- "*the lab was a great learning experience and corresponded to every thing we learned in the class*"
- "*the LDD software, use it more often*"
- "*actual implementation of design concepts learned in class; class was enjoyable and fun"*
- *"the PE exam format"*

Question 12 in the questionnaire asked students how the course can be improved. Following are excerpts from the comments made by students:

- "*more field work and more LDD*"
- "*I would not change much of anything*"
- "*give more time out in the field"*
- "*may be a little bit more technology*"
- "*need more planimetes and more total stations*"
- "*less talk and more filed work!"*

The instructor takes all the comments seriously and usually makes changes in the class and lab in consideration of the comments made.

Conclusion

A CET program as a whole is expected to meet ABET accreditation criteria with contribution from the different courses offered. Upper level courses play an important role in satisfying the criteria. For a design course to meet ABET criteria, specific measurable course outcomes must be outlined to represent what students are able to do when the course is completed. Such outcomes can then be linked to individual items in ABET criteria to gauge the level of satisfaction. In order for the course to meet the demands of industry, the content of the course should be reviewed with input from industry either directly or through industry advisory committee that CET departments usually meet with regularly. It is recommended that class activities be designed for an active learning class environment where all students are actively involved. For assessing student learning, the paper offers an alternative to traditional testing aimed at enhancing student learning beyond the exam and to train students to become more familiar with the Civil Engineering Professional Exam (PE) multiple-choice exam format. It also recommended that Lab activities be designed with objectives including successful teamwork; improving presentation and communication skills; improving writing and lab preparation skills; hands on design experience utilizing design software where possible. Grading student performance and teamwork can be done such that individual accountability is considered in the final grading.

References

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Author Biographies

MAHER M. MURAD is an Associate Professor of Civil Engineering Technology at the University of Pittsburgh at Johnstown. Dr. Murad taught as a visiting professor at Bucknell University and had overseas teaching experience. He also worked as a highway project manager for Acer Freeman Fox International (Hyder Consulting). Dr. Murad received M.S. degree in Civil Engineering from the University of Toledo in 1987 and a Ph.D. in Engineering Science from the University of Toledo in 1994.