A Novel Approach to Expose Students to Global Issues in Civil Engineering and Construction Engineering Management

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Abstract

The availability of new technologies has resulted in great achievements in the civil engineering and construction engineering management fields worldwide. Young engineers should be equipped with the necessary knowledge to perform their jobs in any region of the world, and they should be able to understand the unique cultural and societal environment in which their designs are implemented. Engineering courses need to provide students with the global engineering perspective that will prove beneficial for their careers and this should be done at the early stages of the engineering curriculum. This study proposes a novel approach to expose civil engineering and construction engineering management students to current global issues in engineering and construction practices. An additional goal is the improvement of retention rates by increasing students' interest in the engineering field. The proposed approach consists of encouraging mentoring and collaboration between graduate students enrolled in a research course and freshmen/sophomore students enrolled in an introductory engineering course. The two groups work in teams to prepare a term paper and a presentation that focuses on a comparative assessment between two similar engineering projects, one in the United States and the other in a foreign country with an emphasis on engineering and construction practices and societal, economical and environmental issues. The challenges that we faced during the implementation of the plan and the proposed improvements to the courses are presented.

Introduction and Background

In today's rapidly changing society, the new generation of engineers and construction managers must not only be equipped with advanced technical knowledge but also be able to understand the impact that engineering solutions have on society, environment and economics in a global perspective. Engineering problems are similar everywhere in the world and they are solved according to the physical and mathematical principles at the foundation of engineering science. However, each solution should reflect the unique cultural and societal environment in which it is implemented.

Ideally, young engineers should be exposed to the global issues involved in the engineering profession while they are still in school. Unfortunately, due to the high number of units necessary for graduation compared to other programs, many engineering programs don’t have the flexibility to accommodate additional courses that would provide students with the global engineering perspective necessary to advance their careers. Furthermore, financial constraints may prevent many engineering students from acquiring a broad international experience.

Freshman engineering introductory courses represent an opportunity to fill the gap in this area. In such courses students should learn to see engineering as a profession that, by providing solutions to every-day problems, has implications for individuals as well as society as a whole. Acquiring skills at an early stage will not only increase student interest in pursuing engineering careers, but it will help them to understand and implement innovative design solutions in more advanced courses and it will promote lifelong learning. Freshmen introductory courses, which have been developed at four-year institutions nationwide, familiarize students with the engineering field and improve retention rates[1]. Many of them include hands-on project activities coupled with lectures aimed at the development of problem solving skills and introduction to available resources[1,2,3,4,5]. However, few provide a sufficient exposure to global engineering issues. The importance of this component in engineering education is emphasized by ABET in the list of Student Outcomes included in the 2013-14 General Criteria Section 3[6]. Specifically, Outcome *h* states that engineering programs should provide student with "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context".

While it is beneficial to expose students to engineering as soon as they enter the program, many freshman students often do not possess the necessary background to perform research on their own and to fully analyze the technical aspects of engineering projects. Faculty support is indispensable to guarantee a successful outcome, but peer mentoring could also be an effective strategy to engage students. Peer mentoring programs that employ junior or senior undergraduate students as mentors for freshman/sophomore students, either in freshman courses or in extra-curricular activities, have been extensively implemented to improve recruitment and retention in the Science, Mathematics, Technologies and Engineering (STEM) disciplines[7,8,9,10] to encourage women and minority students to pursue a career in engineering[11,12] and to support undergraduate students working on research and project-based activities[13,14]. These programs may facilitate the transition from high school to higher education, encourage exchange of experiences, and raise the enthusiasm and interest in engineering. However, the level of technical knowledge of potential mentors is limited and a full understanding of the global issues involved in the engineering profession cannot be expected. Graduate students may be more suitable as mentors to undergraduate freshman/sophomores students in engineering introductory courses to work on projects designed to increase student awareness of the global impact of engineering solutions and they could also provide counseling on academic life. Graduate students are typically young professionals who have successfully overcome the obstacles encountered by most students during their academic career, have already acquired enough design experience in senior and graduate courses, and have been exposed to the day-to-day challenges of the engineering profession through their work experience in engineering companies. Many graduate students are also international students who can provide an invaluable foreign perspective on the engineering profession. Yet, because of their student status, they are still considered peers by the undergraduates, thus removing the barriers that usually prevent a more effective collaboration between undergraduate students and faculty members or professionals from industry. Interaction between graduate and undergraduate students through mentoring programs has been implemented at the University of Texas at Austin, and at the University of Colorado at Boulder[15,16]. In both programs undergraduate students were paired with graduate students on research projects for the purpose of improving retention of women and minority students in

engineering to provide undergraduate students with the opportunity to gain research and work experience.

In this paper we present experiences of a recent program at California State University, Long Beach (CSULB) aimed at exposing civil engineering and construction engineering management students to current global issues in engineering and construction practices through mentoring and collaboration between graduate and freshmen/sophomore students.

The Proposed Plan

The College of Engineering at CSULB has developed a series of three one-semester-unit introductory courses to provide students with information regarding the engineering career, the resources available on campus and the basic tools to successfully progress toward their degree. The courses have received GE certification by the University in Category E: "Lifelong learning and Self-development". Two of the courses, ENGR 101 and ENGR 102, are offered at the college level, the third course is offered by each department and is discipline specific.

The discipline specific course offered by the Civil Engineering and Construction Engineering Management Department (CECEM) is CE 101 “Introduction to Civil Engineering and Construction Engineering Management”. This is a mandatory course for all civil engineering and construction engineering management students, including transfer students. About 90 to100 students enroll in this course per semester. The course introduces students to the civil and construction engineering fields. It includes curriculum information and requirements, career paths, and engineering ethics. As part of the requirements for the course in its original format, students worked in teams on a term paper and a presentation that focused on a major engineering project. The course satisfies ABET Student Outcomes *h* –Achievement of the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context -, Outcome *i* - Recognition of the need for, and the ability to engage in life-long learning -, and Outcome *j* - Knowledge of contemporary issues.

Although the selection of a foreign project as topic of the paper provides the students with some insights on different approaches to engineering problems and solutions around the world, in the past, the global exposure has not been systematically implemented throughout the course.

At the graduate level, the Civil Engineering curriculum requires students to take the CE 696 “Research Methods” class. The class focuses on the development of a research proposal to address a specific engineering problem in the area of interest of each student. The proposal is the basis for the project that the students will work on, either in a subsequent class, CE 697 “Direct Studies” or as part of their thesis. The topics selected for the CE 696 proposal often do not include a global engineering component, but the Civil Engineering Masters program serves a large number of international students who represent a valuable resource in term of cultural experience and diversity. About 20-25 students per semester enroll in this course.

During the spring of 2012 the course content of both CE 101 and CE 696 was modified to provide both groups of students more exposure to current global issues in engineering and

construction practices. The modifications were designed by the authors of this paper, who are also the instructors of CE 101 and CE 696. The proposed modifications were as follows:

Modifications Proposed to the CE 101 Course

Term paper and Presentation Content

As part of the requirement for the CE 101 class, students work in teams to submit a term paper and present it to the class as an oral presentation at the end of the semester. The term paper focuses on two projects within a specific civil engineering area. One project has to be in the U.S. and the other in a foreign country. The two projects are selected because there is some similarity between the problems to be addressed. Students are required to analyze the two projects and compare the engineering design and construction practices, and highlight the impact of local environmental, cultural, and societal issues on those solutions. In some cases projects also included an historical component to illustrate how design solutions and technology have developed over time.

Some examples of term paper topics include:

- Skyscraper Design: The World Trade Center Twin Towers, NYC, and the Petronas Towers, Malaysia.
- Bridge Design: The Golden Gate Bridge and the Millau Viaduct in France
- Tunnel Design: The Boston Big Dig and the Channel Tunnel between France and England.
- Dam Design: The Hoover Dam and the Three Gorges Dam in China.
- Water Distribution Systems Design - Differences and similarities in the approach to design water distribution systems in history: The Los Angeles Aqueduct and the Roman aqueducts in Europe.
- Water Pollution. Managing and solving water pollution problems: The Orange County "Toilet to Tap" project and the London Sewers project.

Information should be provided on the purpose of the two projects, their geographical locations, the starting and ending time of construction, the names of the design engineers and the construction company. The main body of the paper and the presentation has to include the following sections:

1. Technical discussion: Students need to describe the main component of the design for the two projects including, if applicable, the structural design, the foundation design, and the design of the components of the projects and highlight similarity and unique features of each design.
2. Discussion on Global Issues: Students need to compare the two projects and analyze both the impact of local cultural, societal, and environmental issues on the specific design solutions adopted for the project in both countries (e.g., availability of materials, different design standards, and environmental impact regulations) and the impact the projects had on local population, environment, and economy. If the project also has an historical component, students are asked to highlight how the design techniques evolved over time and to discuss the impact of technology development on the design.
3. Construction Process: Students need to describe the construction work for each project and compare and contrast the construction processes in the two countries.

Each student team is mentored by two graduate students from CE 696, possibly one international student and one domestic student. Student mentors are selected to match the projects with their expertise. For example undergraduate students working on a project that focuses on skyscraper design are mentored by graduate students specializing in structures. The international student provides mentoring on the foreign project and on the issues that engineers in the foreign country faced and the solutions they proposed. The domestic student provides mentoring on the same topics for the project in the United States. Specifically, graduate students guide the students during the collection and selection of pertinent literature, provide their expertise on the design component of the two projects, and help the undergraduate students to evaluate the global issues related to their projects. In addition, graduate students could provide information to the undergraduate students on non-technical issues such as presentation or writing skills, work-life issues, career or graduate school information.

Lectures
Two lectures are devoted to global issues in civil engineering and construction engineering management. One lecture is devoted to the discussion of the ASCE Report Card on American Infrastructures[17] and the other focuses on the fourteen Grand Challenges for Engineering identified by the National Academy of Engineers[18].

Presentations
In addition to the project presentations by the undergraduate student teams, a lecture is devoted to presentations by two graduate student mentors. The students present their research topic and emphasize the global issues related to their research. The selection is made based on the research topic and its global content.

Assignments
One homework assignment, which in the original format of the course involved a library search to familiarize students with engineering databases and professional journals, was modified in collaboration with the engineering librarian to focus on the specific topic of the term paper. Students are required to perform a literature search and to provide four citations pertinent to the domestic project and four citations pertinent to the international project. At least two of the references should be books, encyclopedia articles, scholarly journals, magazines or newspapers, and two could be authoritative sites from the Internet. Graduate student mentors provide guidance for the selection of appropriate references.

Modifications Proposed to the CE 696 Course

Research Proposal Content
When performing background research for the international project, students are expected to include at least one citation involving an international journal or research group. Students are encouraged to discuss the specific engineering problem they selected for the research proposal from a global perspective. While this could be easily done for an applied research project, it might be a challenge for students who select a more theoretical topic. In this case they are required to identify possible applications of the research results and to discuss their global implications.

Assignments
As a requirement for the class all students serve as mentors for CE 101 student teams as explained in the section above. Graduate students receive 10% of their grade in CE 696 from mentoring assignments.

Presentations
Two students, an "international" and a "domestic" student per semester, are selected to present their research proposals to the CE 101 class as explained in the previous section.

Project Implementation and Preliminary Observations

To evaluate the effectiveness of the proposed changes we decided to implement them in the following step-by-steps fashion:

- Modify and implement selected components of the courses
- Perform an informal assessment to highlight the strengths and weaknesses of the plan
- Perform a formal assessment to evaluate student outcomes
- Develop strategies to improve the student performance
- Implement the remaining proposed modifications

During the Spring 2012 and Fall 2012 semesters we implemented some of the proposed modifications in all the sections of the CE 101 course. We changed the content and format of the term paper and presentations as described and we added the mentorship component, we modified the library assignment, and we introduced two lectures on global issues. At the beginning of the semester the CE 101 instructors divided the students in teams of five to six students and assigned them their project topics. In collaboration with the CE 696 instructor, each team was paired with at least two graduate students. Although we tried to assign one international and one domestic student per team this was not always possible, due to the limited numbers of international students enrolled in the graduate course. An introductory meeting was added to the schedule to give a chance for the CE 101 and CE 696 groups to meet in person in a formal setting. CE 696 students were graded on their attendance at the meeting.

We did not run a formal survey to collect students' feedback, but our own observations from both classes revealed that the major challenge in the proposed plan was the implementation of the mentorship component. Specifically we observed the following:

- Scheduling conflicts: Many of our students at both graduate and undergraduate level hold jobs or internship positions in engineering companies and local agencies and it might be difficult for many of them to find a common time for meeting and discuss the project. Furthermore, our graduate courses are all scheduled in the evening (starting at 6:00 pm) while most of the freshman courses are scheduled in the morning or early afternoon. Availability of graduate students is of major concern because in addition to work, they might also have family obligations.
- High number of mentees per mentor: Due to the high enrollment in the CE 101 course and the relatively low number of graduate students available in CE 696, each pair of graduate students ended up mentoring three teams for a total of 18-20 undergraduate students. This is a very high mentor-to-mentee ratio, which might decrease the effectiveness of the mentoring experience and make scheduling meetings even more difficult.

- Lack of a structured mentoring activity: Because we anticipated problems related to scheduling a meeting time, we decided to leave students the flexibility of scheduling their meetings at times that were more convenient for all team members. We also decided not to make meetings in person mandatory, allowing communication through e-mails and by phone, and we did not require a written record of student progress except for the library assignment related to the literature review that was due toward the middle of the semester.
- Lack of clear guidelines for the project: At the beginning of the semester the CE 101 instructors distributed a detailed description of the project and presentation requirements to their class. However a similar document was not provided to the graduate students. Our assumption was that the undergraduate students would communicate the requirements to their mentors, but this might not always have been the case.
- Lack of interest in the activities and unclear mentorship guidelines: Undergraduate students might not appreciate the importance of receiving guidance and assistance from a more experienced peer. Some graduate students might not be fully aware of what mentorship involves and the benefits that mentorship will provide to their professional development beyond the credit they will receive in the class for participating.

Similar challenges were reported by Attarzadeh et al.[19] while implementing a mentorship program at the University of Houston where seniors were recruited to mentor students in lower-division laboratory courses. The authors proposed a set of strategies to improve the effectiveness of the program.

Proposed Strategies

Below are some of the strategies that will be implemented in our mentorship program based on our observations and suggestions by Attarzadeh et al.[19].

- Resolve scheduling conflicts: We will schedule two mandatory in-person meetings per the semester during class time. To guarantee the availability of the mentors, two lectures in CE 696 will be scheduled so that mentors will have the opportunity to meet face-to-face with their mentees and provide guidance on the project. Unfortunately the CE 101 and the CE 696 classes are currently scheduled at different times during the day and it might therefore not be possible to have all the undergraduate students attending. We will require that at least one student per team participates in these meetings. Furthermore, we will require two more mandatory meetings outside the scheduled class time for both mentors and mentees to meet in person.
- Decrease the ratio of mentor-to-mentee: We will reduce the numbers of team members and we will pair each team with one graduate student based on the focus of the project and the expertise of the mentor to reduce the mentor-to-mentee ratio to one mentor per 5-6 undergraduate students.
- Provide structure to the mentoring activity: As suggested by Attarzadeh et al.[19], in addition to assigning mandatory in-person meetings we will encourage students to communicate by email and by establishing discussion sessions using the class websites, and we will assign a portion of the credit that undergraduate students earn for the paper and presentation to attending the mentoring meetings. Furthermore, we will add an assignment in both classes for which students will earn credit toward their final grade. Prior to each meeting, the undergraduate students will be asked to report on the progress of their paper and presentation

to their mentor. The graduate student mentor will be responsible for reviewing and signing the report, to provide feedback and guidance for the next step of the project, and to prepare his or her own progress report. The undergraduate reports will be turned in to the CE 101 instructor while the graduate student reports will be turned in to the CE 696 instructors for credit on specified due dates.

- Provide clear guidelines for the project: During the introductory meeting, the instructors of the CE 101 course will provide both graduate and undergraduate students with the project guidelines and will discuss the scope of the project, the requirements, and the roles of mentors and mentee.
- Increase student interest in the mentorship activity and train mentors: Attarzadeh et al.[22] highlighted the importance of training mentors in non-technical skills to increase their ability to engage students who might not be interested in either mentoring or in being mentored and to emphasize the benefit that mentees can gain from the experience. To accomplish this, both instructors in CE 101 and CE 696 will devote time in their lectures to explain the scope of the mentorship activity, the role of mentors and the benefit that both mentors and mentees will gain professionally from participating.

Finally we will develop a formal survey to assess the effectiveness of the proposed strategies and we will define specific student outcomes and assessment tools in both classes to quantitatively measure student performance.

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