

AC 2007-1011: THE ROAD TO THE GLOBAL ENGINEER: USING LIBERAL ARTS PREREQUISITES EFFECTIVELY IN ENGINEERING DESIGN

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The Road to the Global Engineer: Using Liberal Arts Prerequisites Effectively in Engineering Design

Abstract

This paper examines the role liberal arts education plays in providing the engineering student with tools that will foster the development of global engineers. Students were required to not only prepare traditional designs and write reflections in essay format about the impact of their designs. The reflections provided rich data for this study. The data gathered offers a glimpse of the characteristics of a global engineer and provides an insight into the role that engineering educators can play in creating engineers who are flexible, adaptable, resilient and ultimately lifelong learners. A proposed method that provides an opportunity to reflect on integration of liberal arts courses is offered. This method can be utilized in the classroom to ensure that engineering educators are molding a global engineer.

Introduction

The importance of liberal arts courses as part of an engineering curriculum has been debated for decades. When discussing liberal arts coursework, it is not only those math and science courses which are applicable to technical classes, but also humanities and social science courses which are requisites or electives necessary for degree completion. Many argue that there is so much technical material that an engineering graduate needs to know that there is no room in the curriculum for more liberal arts education. Others argue that the global engineer must have a solid foundation in liberal arts education. It is important to note that the global engineer is the engineering professional who takes into account the social, environmental and economic implications of her/his designs and acknowledges that these implications have an influence on not only the immediate benefactors of the design, but on other individuals and processes within society. Recently the latter argument is prevailing.

A number of engineering departments in recent years are choosing to re-evaluate and revise the curriculum, offering students the opportunity to enroll in more liberal arts courses in support of training and equipping the global engineer. The accreditation standards for engineering education now entail producing graduates who are able to relate engineering to its social implications as well as understand the global impact of engineering. Liberal arts coursework prepares the student engineer to meet those standards.

To increase the relevance of humanities coursework, engineering educators need to provide their students with opportunities to incorporate this knowledge into their engineering work. The marriage between humanities and engineering coursework facilitates is the next practical step in advancing engineering education. In the 2004 NAE report, it was suggested that Global engineers of the future will need to “use new tools and apply ever increasing knowledge in expanding engineering disciplines all while considering societal repercussions and constraints”⁸ (National Academy of Engineering, 2004, p. 43).

One of the “new tools” engineers will need is the ability to critically reflect, consider other perspectives, and recognize the various human and social factors that go into a design. To suggest that prior to now engineers did not consider the human and social issues would be erroneous; however, it is important to note there is a changing political and social consciousness in the United States that calls for added attention to long-term social and humanitarian concerns. Practical training about different perspectives begin in the classroom. Humanizing the engineering design process in the classroom prior to entering the workforce will help to ensure the consistent practice of considering the sociological and ecological concerns in the design process by the engineer. This paper describes a study in which a reflection tool, which asks students to think about how knowledge from prior courses both technical and non-technical was applied to the design process, is used as a means of training engineering students to incorporate prior knowledge, including their liberal arts education, into the engineering designs.

Purpose

Engineering projects not only require the incorporation of sound technical skills, but also the integration of the social, legal, economical, historical and political constraints that define the range of solutions to engineering problems. It is hypothesized that the opportunity to reflect allows the designer to first recall and then incorporate these constraints into the design. The purpose of this exploratory study was to investigate the effectiveness of teaching the reflection process in an engineering class in order to develop integrative, global and socially conscious engineers. Thus, this paper seeks to promote Boyer's (1990) argument that effective teaching stimulates "active, not passive, learning and encourage[s] students to be critical, creative thinkers, with the capacity to go on learning after their college days are over"² (p. 24).

This study examined the effectiveness of teaching the reflection and integration process in an engineering class by creating opportunities for engineering students to reflect on prior knowledge during the design of an engineering project. It also examined the level of integration of that knowledge in project designs. The data gathered offers a glimpse of the characteristics of an integrative engineer and provides insight into the role that engineering educators play in producing engineers who are able to consistently utilize flexibility, adaptability, and resiliency to ultimately become lifelong learners. Overall, this research provides a framework for engineering educators for reforming the engineering classroom so that the curriculum is more meaningfully linked to the humanities and social sciences courses from the liberal arts scope and technical components of the curriculum and thus enhancing the likelihood of developing reflective, integrative and socially conscious engineers.

The major research question for this study was: What is the impact of integration of prior knowledge on the development of socially conscience engineers? With this question, we examined the "vision of the possible aimed not so much at proving (or disproving) the effectiveness of a particular approach or intervention but at describing what it looks like"⁵ (Hutchings 2000, p. 4). The descriptions provided allows other engineering scholars to use reflection and integration strategies in the engineering classroom in order to produce engineers who make reflection a consistent practice in their careers. This question allows for the heuristic possibilities by introducing a new conceptual framework for both teaching and learning in the engineering classroom. Hutchings (2000) purports that "formulating a new conceptual framework shapes thought about practice"⁵ (p. 20). Overall, the results of this work will be of interest to engineering educators who wish to make more effective use of the liberal education that engineering students have and use that education to aid the development of socially conscious engineers.

Methods

Data was collected during the fall semester of 2005 from a sample of senior engineering students enrolled in a senior level design course entitled Foundation Engineering. This one-semester, three-credit course is offered once a year. The primary goal and objectives of the course were to acquire an understanding of the basic concepts of foundation design, to appreciate the importance of life long learning, to develop self study learning and integrative thinking skills, to develop presentation skills and to acquire team work experience. The study location was a mid-size Mid-Atlantic research university. The sample consisted of eight students—two females and six males. All of the students were under the age of 22 years and have plans to either enter the engineering workforce immediately or continue on to graduate school upon graduation. Voluntary consent to participate was obtained by all study participants.

Each participant in the study was assigned four projects—a retaining wall, a landslide mitigation analysis, a structure settlement analysis, and a building foundation design. Each assignment not only differed in what was designed, but also in the size of the design team and the audience for the finished project. Participants prepared designs as individuals, pairs and groups of four. The audience for the projects varied in the degree of technical skills from a layperson audience typically found at a town meeting to a scientific but non-engineering audience to an engineering client. A summary of the assigned projects is given in the table below.

<i>Project</i>	<i>Audience</i>	<i>Presentation Format</i>	<i>Design Teams</i>
Retaining Wall Design	Engineering Student (underclassman)	Letter	Teams of 4
Landslide Assessment	Scientific Audience	Electronic	Teams of 4
Settlement Analysis	Lay Audience (Town Meeting)	Electronic Poster	Pairs
Building Foundation	Civil Engineers	Technical Report	Individuals

Along with the design calculations and drawings, the participants were required to first stop and reflect on prior knowledge from not only engineering coursework but from coursework in the humanities and social sciences, social constraints that may have effected the design process and past experiences in both design and in courses and then craft a reflective essay in which they described how they incorporated their reflections into their projects. In addition, the students completed an end-of-course evaluation in which they wrote about the effectiveness of the reflection and integration process. It is these reflective essays and course evaluations that were the primary source of data for this study.

Data Analysis

Careful analyses of the qualitative data collected in this study have led to several observations about student engineers who were reflective and integrative. We assert that these observations when present in an engineer enhance the social consciousness of the work that is done. The assertions are:

1. *The integrative engineer is aware that the ability to incorporate previous knowledge is a crucial component in engineering design.*
2. *The integrative engineer understands and practices the incorporation of human interest factors when designing projects.*
3. *The integrative engineer is self-evaluative throughout the project design.*
4. *The integrative engineer can readily adapt language to varied audiences.*

The assertions are accompanied by examples pulled from course evaluations and reflective pieces submitted with projects. All students are provided with aliases in order to maintain confidentiality with the reflective essays. As the course evaluations were completed anonymously, no names will be provided for any citations used. The examples are cited as reported in order to maintain the integrity and validity of the responses.

Interpretations

Assertion #1: The integrative engineer is aware that the ability to incorporate previous knowledge is a crucial component in engineering design.

By the end of the semester, a number of students were able to reflect in a manner which supports this assertion. One student stated:

“The real fact was that integration was always being used however it was not being acknowledged until this point. The acknowledgment of this fact encouraged a wider scope for the integration to also include social sciences which are often overlooked by engineers for example economics in referring to walls and landslides.”

When reflecting on the shallow foundation project, Brittany stated “basic geometry and statics were important elements in the final analyses.” This acknowledges that information acquired in prior courses were helpful in completing the project. In a group reflection submitted by Brittany, David, Carl and Frederick pertaining to the landslide project, they argued “prior knowledge is an engineer’s most effective tool in analysis; reflection on knowledge allows the engineer to efficiently solve problems.” These examples illustrate how the engineering student depended on prior knowledge and by reflecting on that knowledge they became more aware of its importance and relevance in their design projects.

Assertion #2: The integrative engineer understands and practices the incorporation of human interest factors when designing projects.

Often times in the engineering classroom, the impact these structures and designs will have on society is not addressed. The intense focus on the technical aspects of the design has led to a devaluation of the social aspects that may have a critical affect on the design. The liberal arts courses that engineering students take coupled with their life experiences provide the foundation for their awareness of human factors that they may need to consider in all design projects. In *The Engineer of 2020: Visions of Engineering in the New Century*, it clearly states that “engineers must know how and when to incorporate social elements into a comprehensive systems analysis of their work”⁸ (National Academy of Engineering, 2004, p. 35).

In the course evaluations, there were observations made about the importance of considering the impact an engineer will have on humanity when constructing and designing projects. Students argued “[the reflection process] helped because we were forced to apply the information and new [technical] concepts to everyday life situations.” Further, when discussing the global impact of their designs they asserted “I think that it in a sense “humanized” the engineering process moving away from the calculations for a while and think[ing] about the people and environment that we are designing for ...a feature I think is key to engineers” and “...the design of a retaining wall exposed us to the technical aspect of a design project, and through reflection, the socioeconomic and environmental concerns as well.” The ultimate benefit that the design would be for humanity was an overarching concern as illustrated by this statement in the evaluation:

“The reflections really helped. Even if the previous knowledge was not applied directly to the solution, it was still taken into consideration and analyzed as to how it would affect the ultimate good in solving the problem.”

In their reflective essays students spoke of a number of societal factors that had impact on their designs. For example, Brittany, Carl, Frederick and David clearly stated the importance of including the human factor when they asserted “in reflecting upon the work done, the engineer must take the mandate to inform the public of [the] constraints that are present.” In a partner reflection with Alan and Frederick, they explained “factor[s] of noise pollution, air pollution and human psychology play significantly... [these] are problems that would need to be anticipated.” Here, these two students considered the impact a settlement foundation will have on not only the building and any surrounding structures, but also its ecological and environmental contributions to society. David explained in his reflection on the shallow foundation project “if proper time management is not implemented then this could result in the project not being finished on time which usually causes an increase in cost to me and debases my credibility and opportunity to be rehired or contracted to do another job,” recognizing economic consequences and professional impact of his work.

The “humanized process” referenced in the above reflections are important when discussing the integrative engineer. The ability of an engineering student to “actively construct and discover and transform their own knowledge”¹² (Smith & Waller, 1997, p. 4) helps the student to incorporate social aspects in technical thought processes. Humanizing the technical process in the classroom prior to entering the workforce will encourage the consistent practice of considering the societal impact in the design process by the professional engineer. This consideration is important because global engineers of the future will need to “use new tools and apply ever increasing knowledge in expanding engineering disciplines all while considering societal repercussions and constraints”⁸ (National Academy of Engineering, 2004, p. 43).

Assertion #3: The integrative engineer is self-evaluative throughout the project design.

In Evan’s reflective essay on shallow foundations, he demonstrated a clear understanding of this assertion. He explained “reflection is an exciting tool... [to show] where an engineer can put his/her focus ...to bridging the gap of the technical with the philosophical and the sociological”. This statement indicates the engineer must constantly think about any and all contributing factors in the design, construction and presentation stages of a project. In order for the engineer to “bridge a gap” s/he first must know where the gap lies in relation to project design and then determine whether or not the “bridge” was effective in uniting “the technical with the philosophical and the sociological.”

Assertion #4: The integrative engineer can readily adapt language to varied audiences.

The role of the global engineer is to effectively engage multiple stakeholders. Therefore, the integrative engineer must have the “ability to communicate convincingly and to shape the opinions and attitudes of other engineers and the public”⁸ (National Academy of Engineering, 2004, p. 55). The ability of the integrative engineer to present results of design to any audience is important because it shows the integrative engineer is adaptable, able to tailor the language of findings to suit a variety of audiences. In the reflective essay on the foundation settlement analysis, Brittany and Evan were able to utilize language that would be appropriate for a town hall meeting audience which may include individuals with varied levels of technical skills. They purported “design sometimes takes you away from the left brain competence to the right brain mediocrity...the two sides of the brain must now be integrated to formulate the solution for the problem at hand.” It can be argued that the use of the left brain and right brain analogy implies tailoring language to the audience. At first glance, it may seem self-aggrandizing with an underlying slight to the right brain, as this is a way of thinking often attributed to students and thinkers in the humanities, there is still an acknowledgement of its function in the design process.

The shallow foundation project was intended to be the most technical, with a reflective essay addressing a technical audience. This project was the last task assigned. David used quotes to enhance his reflection: “It was George Washington who said ‘we ought not to look back unless it is [to] derive useful lessons from past errors and for the

purpose of profiting by dear-brought experience.” This quote not only incorporated a means of allowing the audience to connect to the reflection, but also provided another way of illustrating the reflection process. The use of a quote from George Washington is also a demonstration of how the student was able to integrate knowledge from history and the social sciences into his engineering design reflection.

Conclusion

The results of this study have shown that although integration of prior knowledge and experiences is a learning component that has always been present in the engineering design classroom, there is value in encouraging students to consciously reflect on that knowledge and its impact on their design work. The reflective tool implemented in the Foundation Engineering course allowed the students to consider the human factors in their design. This tool is easily incorporated in other design courses and has the added benefit of developing student writing skills. The implications of this work suggests that these students will have greater social consciousness, be more sensitive to the social consequences of their work, and become more effective communicators with the constituents in the global workplace.

The concerns surrounding diversifying the engineering workforce have traditionally been linked to research with underrepresented groups. However, as we aim to produce a “global engineer,” issues of diversity emerge not only among the human capital of engineers but the contributions that can be made by a diverse curriculum in engineering education. The engineer grounded in the liberal arts is the key to achieving that goal.

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