Is Covering Ethics in an Analysis Class Effective?

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Abstract

Most engineering educators will agree that engineering ethics is an important component of a complete undergraduate engineering education. There are many approaches as to how to cover ethics in an engineering curriculum. Some programs have elected to cover ethics in a required three credit hour lecture course, sometimes taught by a philosophy department instructor. Many others have a piece-meal method of delivering ethics education to students. In this scenario, the students may have an introductory lecture as part of an intro to engineering class. A one credit hour ethics class may be required or ethics can be touched upon in other classes, where ever it is most appropriate. Finally, ethics is again covered during a senior capstone type of class. Just how effective is this type of delivery? A series of two surveys were given to junior level civil engineering students. The surveys focused on ethical use of computers. Prior to the first survey, all students had taken a one credit hour engineering ethics course or an intro to engineering course. The students then had several weeks of a structural analysis class. Engineering ethics was touched on during several of lectures, with two of those lectures having a computer usage focus. A second survey was given. The results of both surveys were compared. The comparison indicated that this type of delivery is an effective means of covering a specific topic in engineering ethics.

Introduction

Engineering programs throughout the nation have been grappling with the dilemma of how to best incorporate engineering ethics into their curricula ever since ABET required engineering ethics to become a part of an accredited program. There are many approaches that an engineering program can take in order to implement this ethics requirement. Some engineering departments elect to teach ethics as a one to three credit hour stand alone lecture/discussion course [1]. Others incorporate ethics in short discussions scattered throughout the curricula. Finally, some schools cover ethics within select courses such as an introductory engineering freshman class, a senior capstone class, or other classes as separate stand-alone lectures.

This paper will first discuss the method that the Department of Civil and Environmental Engineering, CEE, at the University of New Orleans, UNO, has used to effectively provide civil engineering undergraduates with an understanding and knowledge of engineering ethics. The department recently has modified this method of delivering engineering ethics to students based on student feedback. Following this discussion are the results of two surveys of junior civil engineering students taking a required structural analysis class. The first survey was given to the
students on the first day of class prior to any lecture. The same survey was then again
administered to the same class at mid-semester. The surveys questioned these students about
professional issues such as professional licensure and ethical issues, particularly those regarding
ethical use of computers in engineering analysis and engineering design. Some questions
regarding background information was also asked. This information included work history and
the type of desired engineering employment upon graduation. A comparison of the pre-lecture
and post-lecture survey indicated that knowledge of professional and engineering ethics issues
increased during the duration of the structural analysis course.

Background

Original Coverage of Engineering Ethics

Engineering ethics is a subject that is treated seriously at UNO. Of course the department must
fulfill the ABET requirement, but it must also consider another issue: that of licensure. The State
of Louisiana now requires that all registered Professional Engineers maintain licensure via
continuing education. Thirty professional development hours of continuing education are
required in Louisiana every registration period (two years). One of those hours must be in
engineering ethics. Since most UNO CEE graduates stay and work in the metro area upon
graduation, and many civil engineers do become registered Professional Engineers, the topic of
engineering ethics and how it is delivered to engineering students has been given much
consideration.

Up until 2003, UNO CEE delivered engineering ethics in a piecemeal fashion. Students were
first exposed to ethics in a three hour lecture as part of a freshman introduction to engineering
course, Engineering 1000 [2]. At the time, this course was a required one credit hour course for
students in all engineering disciplines.

The Engineering 1000 course topics included:

- Various disciplines in engineering (i.e., civil, mechanical, electrical, marine)
- Measurement, dimensions, units
- Computer applications and graphing
- Ethics (National Society of Professional Engineers Code of Conduct)
- Memory, motivation, study and communication skills, time management
- Statistics
- Problem solving and engineering design

As a sophomore, the student then took a one credit hour (one hour lecture) course on engineering
ethics. This class also focused on professional conduct as mandated by ASCE, NSPE, and the
State of Louisiana’s board of registration for professional engineers and land surveyors. There is
also discussion of case studies that illustrate ethical issues that may be encountered in
professional practice. Computer ethics was not touched upon, due to lack of time.

The student was then again exposed to engineering ethics as a senior. Ethics was covered as a
one class three hour lecture in both the senior capstone course and senior seminar (a FE preparation course). The primary focus of these lectures on engineering ethics was professional conduct. These courses are both required for graduation. Was this method effective? The pass rate for the ethics portion for UNO students taking the FE was above average. Why change?

Modified Coverage of Engineering Ethics

In 2004, all departments within the UNO College of Engineering elected to remove the one credit hour ENGR1000 Intro to Engineering requirement from their curricula due to poor student evaluations. It is estimated that 10-20% of the students did not take ENGR1000 as freshman. Many took it as juniors or seniors. The course syllabus was specifically designed as an introductory course meant to be taken by incoming freshmen with very limited knowledge of engineering. Upperclassmen of course would not find much of the course content relevant to them. The presence of these upperclassmen in ENGR1000 had a probable negative impact on the course evaluations.

Engineering ethics continues to be delivered to the undergraduate civil engineering student through PHIL2244, Engineering Ethics, which is a one hour lecture course taught by an instructor from the philosophy department. The course touches on the NSPE Code of Professional Conduct, as well as various case studies involving engineering ethics. Ethics is still part of the senior capstone and senior seminar FE preparation courses.

Ethical Use of Computers in Structural Engineering

Leroy Emkin, professor of structural engineering at Georgia Institute of Technology’s Department of Civil and Environmental Engineering, has given keynote addresses at several conferences since 1998 on the topic of misuse of computers in structural engineering. Dr. Emkin is also one of the founders of GT STRUDL, a finite element software package used extensively for structural design. He fears that analysis and design software is getting so sophisticated that many engineers will rely on computer generated results that have not gone through the rigorous system of checks that hand calculations historically had [3].

Emkin says: “…that it appears that the least experienced, least knowledgeable, and youngest structural engineers are given primary responsibility for using computer software to solve exceedingly complex structural analysis and design problems…It is often the case that the inexperienced young engineer using the computer has limited knowledge of the underlying principles of structural mechanics and the basis of code design provisions. Such engineers have the most difficulty judging the assumptions and procedures inherent in the computer program’s computational algorithms, and subsequently judging the quality and relevance of the results of the computer’s operations. Rather than questioning all results delivered by the computer and validating all results against independently created problem solutions, the inexperienced engineer often, out of frustration or lack of knowledge, will accept whatever results are output by the computer program as correct…”
Emkin has suggested some minimum standards for computer related quality. They are listed in abbreviated form here.

- Engineers must qualify and certify software vendors before software purchase
- Engineers must validate and certify computer software products prior to use for structural engineering
- Engineers must apply the same high degree of care and detail when validating computer software accuracy and checking actual computer results as is applied when using time tested and traditional procedures for checking hand computations
- Persons without sufficient structural engineering knowledge and experience which would qualify them to be fully and legally responsible for structural engineering designs should not be allowed to use the computer software without careful and complete supervision by a competent, experienced, knowledgeable, and responsible structural engineer. In other words, a good computer program does not make a good engineer, only a good engineer should use a good computer program!
- Engineering managers must set examples and provide incentives and comprehensive training programs for the proper use of computers in the structural engineering design decision-making process.
- The engineering education community must recognize the urgent need to include in their curricula the issues of how the computer environment impacts areas of engineering liability, quality of engineering computations, procedures for assuring software quality, and qualifications of engineering computer professionals.
- Professional engineering societies must establish and aggressively promote guidelines for the proper use of computers by structural engineers.
- Government regulatory agencies that are charged with assuring the safety of the general public must develop regulations (and appropriate penalties) to protect the public from the dangers of improper use of computers in structural engineering analysis and design.

Are UNO CEE students prepared by the present curricula to handle ethical issues in regard to the proper use of computers in engineering analysis and design?

Survey of Juniors in ENCE3356 Structural Analysis

In the fall semester of 2004, two brief questionnaires were given to all students in ENCE3356 Structural Analysis. Structural Analysis is a four credit hour lecture class that incorporates two traditional civil engineering classes, the analysis of determinate structures and the analysis of indeterminate structures, into one class. The thrust of the surveys was twofold. The author wanted to find out how well the students had been prepared to handle computer-related ethical dilemmas. The author also wanted to ascertain if the students understood some basic professional issues. The first survey was administered on the first day of class prior to any lectures. The second survey, which was a mirror of the first, was given after mid-semester. During the first half of the course, brief discussions were sprinkled throughout which focused on the ethical use of computers in engineering analysis and design. The topic was particularly relevant during the four hour lecture which covered the required use of computer software for analyzing plane framed structures [4]. Twenty three students responded to the first survey and 20 students responded to the second survey. The survey is now provided.
Survey of ENCE 3356 Students on Structural Engineering

Background Information

I am a  (1) undergraduate  
(2) graduate student  

My employment history (both past and present)  
(1) have never been employed  
(2) have always been employed in a business unrelated to engineering  
(3) am working/have worked for an engineering firm  
(4) am working/have worked for the Corps of Engineers  
(5) am working/have worked for a company associated with engineering  
(parish/state gov., company selling technical services or products, etc.)  

Upon graduation, I would most likely seek a job that allows me to do:  
(1) structural engineering  
(2) water resources (supply, drainage, etc.) engineering  
(3) environmental engineering  
(4) geotechnical engineering  
(5) technical sales  
(6) other  

Professional Issues  

Code for next set of questions: 
(1) = describes situation fully  
(2) = describes situation well  
(3) = describes situation somewhat  
(4) = describes situation not at all  
(5) = not applicable  

___ I know the difference between an Engineering Intern and a Professional Engineer.  

___ When I graduate from UNO, an ABET accredited engineering program, with a BS in Engineering, I can legally call myself an engineer.  

___ When I become an engineer, I will use canned computer software in analysis and design.  

___ Computer output is always correct, if the input is correct.  

___ When my future employer purchases technical software, I will be involved in the selection decision.  

___ I will always run a trial problem with a known solution in order to validate technical software that I use for the first time, even if the software is widely used in my industry and has an excellent reputation.  

___ I will always do a quick hand calculation in order to check if results of a computer analysis/design are as expected.  

___ A failure occurs in a system that you designed using a canned computer software. Your input is all in order, but the results are found to be incorrect. The software writer is liable for the damages due to the failure.  

COMMENTS
Results of the survey

General

The data in Table 1 shows the makeup of the respondents of both surveys. Two graduate students dropped the course. Graduate students enrolled in this class are usually engineering graduates from other disciplines desiring to get a masters degree in civil engineering.

### Background information

<table>
<thead>
<tr>
<th></th>
<th>First survey (Pre)</th>
<th>Second survey (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undergraduate</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Graduate student</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 1: Number of undergraduate and graduate student respondents

Table 2 lists the employment history of the respondents. UNO, as an urban university, caters to an atypical college student. The respondents were found to be typical UNO students in that they did have job responsibilities. Many were returning to school after or while working a full time job. Most students worked for an engineering or technical/service company.

### Employment History:

<table>
<thead>
<tr>
<th></th>
<th>First survey (Pre)</th>
<th>Second survey (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Always but unrelated to engineering</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Working/ed for engineering firm</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>Work for US Army Corps of Engineers</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Working/ed for service/technical company</td>
<td>7</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 2: Employment history of student respondents

The results from the career aspiration question, Table 3, curiously show that most of the students wanted to become structural engineers upon graduation.

### Upon graduation, I will seek employment as a:

<table>
<thead>
<tr>
<th></th>
<th>First survey (Pre)</th>
<th>Second survey (Post)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural engineer</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Water resources engineer</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Environmental engineer</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Geotechnical engineer</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Technical sales engineer</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 3: Employment aspirations of student respondents

The usual comment specified under the “other” designation was “construction engineer”.

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Engineering Ethics

The results of the ethics portion of the two surveys are given in Figures 1 – 8. Questions A and B focus on professional issue questions. It was found that most students knew the difference between an EI and a PE on the first day of class. However, most students did not fully understand the legality of the title “Engineer” at that time.

**A: I know the difference between an Engineering Intern and a Professional Engineer**

![Comparison of pre-lecture and post-lecture survey results from question A](image)

Figure 1: Comparison of both pre-lecture survey and post-lecture survey results from question A

**B: When I get my BS from an ABET-accredited program, I can legally call myself an engineer**

![Comparison of pre-lecture and post-lecture survey results from question B](image)

Figure 2: Comparison of both pre-lecture survey and post-lecture survey results from question B

Questions C through H (Figure 3 – 8) were focused on computer ethics and proper computer usage in engineering design. A “1” indicates that the situation is described fully, “2” - well, “3” – somewhat, “4” – not at all, and “5” – not applicable.
Many students did not realize that computer software plays a significant role as a tool in engineering design, see Figure 3.

C: When I become an engineer, I will use software in analysis and design that I did not create

![Figure 3: Comparison of both pre-lecture survey and post-lecture survey results from question C](image)

The data in Figure 4 shows that many students did not realize that computer output is not always correct, even if the input is correct. By midterm, most students understood that computers and computer code is not infallible.

D: Computer output is always correct, if the input used in the analysis is correct

![Figure 4: Comparison of both pre-lecture survey and post-lecture survey results from question D](image)
The data in Figure 5 shows that by mid-semester most students realize that they should be involved in the selection of computer software for use in engineering analysis and design even though the employer is purchasing it.

**E: When my future employer purchases technical software, I will be involved in the decision**

![Figure 5: Comparison of both pre-lecture survey and post-lecture survey results from question E]

The data in Figure 6 shows that the ethics coverage prior to the analysis class provided the students a good ethics background with regard to validation of software used in engineering design.

**F: I will always run a trial problem with a known solution in order to validate software that I use for the first time**

![Figure 6: Comparison of both pre-lecture survey and post-lecture survey results from question F]

More students by mid-semester indicated that a hand calculation should be done as a check of
Most students knew that a computer software vendor/creator is not liable for a failure of a system or structure analyzed or designed using the software at the time of the first survey. This issue was stressed during the weeks between the times that the two surveys were administered, and still several students did not understand that the software vendor does not assume any liability for proper design.
Conclusions

Engineering ethics is presented to civil engineering undergraduate students at the University of New Orleans via a one credit hour engineering ethics course (sophomore level) and one lecture each in the senior capstone course and senior seminar FE preparation course. Other courses may devote time to ethics coverage. One such course is a junior level structural analysis course. In this course students learn how to ethically use a plane frame structural analysis program, similar to those used in practice for structural design. A comparison of the results of the “pre” and “post” surveys indicated that in general the majority of the students had a good understanding of professional issues and computer ethics as it related to engineering design and analysis prior to the ethics lectures in analysis class. Other findings include:

- Prior to the computer ethics lectures in the analysis class, many students did not know that computer software purchased from a vendor is often used in practice for engineering design and analysis.
- Prior to the computer ethics lectures in the analysis class, many students assumed that computer output is always correct if the input is correct.
- Prior to the computer ethics lectures in the analysis class, many students did not realize that they should be involved in the selection of engineering software to be purchased by their employer.
- Prior to the computer ethics lectures in the analysis class, many students did not know the importance of a hand calculation check of computer output.
- Prior to the computer ethics lectures in the analysis class, many students did know that they should validate software used for the first time.

In closing, engineering educators cannot assume that all aspects of engineering ethics are being taught to the student. If a specific area of ethics is very pertinent to a sub-discipline of an engineering program, that information may not be covered in a general engineering ethics course. However, it can effectively be integrated within specific relevant engineering analysis or design classes.

REFERENCES


NORMA JEAN MATTEI is an associate professor in the Civil and Environmental Engineering Department of the University of New Orleans. She teaches structural engineering analysis and design classes. Her research areas include diversity, experimental structural and materials testing, engineering ethics and residual stress measurement using electronic speckle pattern interferometry.

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