Integration of Professional and Ethical Responsibility into a Computer Applications Course

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Abstract – A module on professional and ethical responsibility from a sophomore level Computer Applications class is described and the impact on students' opinions is assessed. The module focused on the tenets of intellectual property, license agreements, privacy, and truth in software. Students were given a pre-test covering a variety of situations they are likely to encounter during their academic carrier. Immediately after the pre-test, an active learning environment was created by forming groups of students and assigning each group one of the situations from the test to consider, then develop and present the group position. The two professors team-teaching the course facilitated the discussion session, then provided the correct answer and resolved remaining student questions. After the active learning session, the test was repeated to allow the impact of the module to be assessed. Based on a comparison of pre- and post-test results, the average deviations from the correct responses were reduced by 5% to 75% in one course section and from 75% to 100% in the second section. A 20% - 100% reduction in the RMS of the deviations from the correct responses for almost 90% of the situations tested supported the effectiveness of the module.

Keywords: ethics, professional responsibility, assessment, computer

INTRODUCTION

Criterion 3(f) of the Accreditation Board for Engineering and Technology's (ABET) "2004-2005 Criteria for Accrediting Engineering Programs" [1] requires engineering programs to demonstrate that their graduates have "an understanding of professional and ethical responsibility." Further, Criterion 4 (the Professional Component) stipulates that the "knowledge and skills acquired in earlier course work" prepare students for their major design experience acquired toward the end of their academic career, which in turn helps prepare students adequately for engineering practice. One of the engineering standards and realistic constraints that must be incorporated into the students' design experience is ethical considerations.

This purpose of this paper is to describe what has been done in a sophomore level Computer Applications for Civil and Environmental Engineering course to teach and improve professional and ethical responsibility. The module integrated into the computer applications course is only part of the department's overall efforts in teaching professional and ethical responsibility. Core elements of the computer applications course include programming in a non-traditional environment (Mathcad) and use of an array of tools such as 2-D and 3-D plotting, symbolic processor, statistical functions, video, and integration of other software packages. Topics covered in the ethics segment of the course include privacy, truth in software, intellectual property, copyright, license agreements including public domain and shareware. Team teaching is used throughout the course and the professional and ethical portions are taught with active learning techniques.

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To assess the ethical course module, students are given a pre-test and a post-test. Also included in the paper is a description of how the department's approach to assessment and continuous improvement has been used to enhance the professional and ethical component of the course.

BACKGROUND

ASCE's (American Society of Civil Engineers) *Body of Knowledge* [2], a report designed to extend the frontier for preparing future civil engineers for professional practice, fully incorporates ABET's Criterion 3 in its own outcome model. For each Body of Knowledge outcome corresponding to an ABET Criterion 3 outcome, a commentary is provided that sheds light on how the outcome may apply to civil engineering practice. For ABET Criterion 3(f), the following commentary is provided:

> The civil engineer is to hold paramount public safety, health, and welfare. A thoughtful and careful weighing of alternatives when values conflict is crucial to the responsible conduct of engineering. Therefore, civil engineers practicing at the professional level need to demonstrate an understanding of and a commitment to practice according to the seven Fundamental Canons of Ethics[*] and the associated Guidelines to Practice Under the Fundamental Canons of Ethics. [2]

Not only does this commentary link the importance of understanding professional and ethical responsibility to subsequent practice as a civil engineer, it illustrates why Criterion 4 regards ethical considerations to be an important element of a major design experience (e.g., capstone course).

Two primary avenues are available for institutions to provide students with an understanding of professional and ethical responsibility. One avenue is a course or courses dedicated to teaching ethics. A second approach is to teach ethics across the curriculum as components of a number of courses.

In a study of ethics instruction, Haws [3] reviewed 42 papers appearing in the proceedings of the ASEE (American Society for Engineering Education) Annual Conference. The 24 papers that address undergraduate courses are summarized in Table 1. Courses were equally divided between upper and lower divisions, and the majority of the courses included ethics as a component rather than a central topic. Among the 42 papers surveyed, Haws [3] placed the courses in one of six categories: professional engineer's code of ethics, humanist readings, theoretical grounding, ethical heuristics, case studies, and service learning.

Creative teaching techniques that have been used with ethics modules and courses include group projects, role-play, writing assignments, discussion, Socratic dialogue, mock court, and personal testimony of practicing engineers [3,29]. Santi [30] presents a number of exercises that may be used for teaching ethics in civil, environmental, and geological engineering. These include billing, bad news, written opinions, misinterpretation, relating to your employer – time off, relating to your employer – desirable traits, pubic meeting, sixty-seven professional practice rules, and ethics policy statement.

COURSE ASSESSMENT AND IMPROVEMENT

Criterion 2(d) of the ABET Criteria [1] requires an engineering program to have a system of continuing assessment to demonstrate that its program objectives are achieved and that the results were used to improve the program. The system must promote continuous improvement.

As part of the Department of Civil and Environmental Engineering's (CEE) overall assessment process, each course is assessed by the instructor. Results are ultimately incorporated into an annual report that is reviewed by an assessment committee and the department head. Suggestions for improvement made for each course are an

[*] The seven fundamental canons of ASCE's Code of Ethics may be found at http://www.asce.org/inside/codeofethics.cfm

Table 1. Undergraduate Courses with Ethics Content Featured in ASEE Annual Conference Proceedings, 1996-1999 [3]				
Number of Papers	**Type Course**	**Level**	**Ethics a Component of a Course or a Central Topic**	**Reference**
5	Capstone Course	Upper	Component	[4-8]
1	Professional Practice Course	Upper	Component	[9]
2	Technical Course	Upper	Component	[10-11]
4	Courses Involving Social Issues	Upper	Central	[12-17]
4	First-year seminars and Introductory Courses	Lower	Component	[18-21]
2	Composition	Lower	Component	[22-23]
1	Mechanical Engineering Technology Capstone Course	Lower	Component	[24]
2	Economics and Management (Integrated)	Lower	Component	[25]
3	Social Responsibility Courses	Lower	Central	[26-28]

important part of each individual course assessment. During the review process, course assessment items are separated into one of three categories for further processing. For one of the categories, a professor uses the course assessment items to improve the next offering of the course. The other two categories involve coordination with other professors teaching the same course or with a committee such as the department curriculum committee. A more complete description of the department's overall assessment process is presented elsewhere [31].

COMPUTER APPLICATIONS FOR CIVIL AND ENVIRONMENTAL ENGINEERING COURSE

During the mid – 1990s, the Department of Civil and Environmental Engineering switched to a non-traditional language (Mathcad) for its programming course – CIVL 209 (Computer Applications for Civil and Environmental Engineering). Prior to that time, a number of programming languages had been used, including FORTRAN, BASIC, QUICKBASIC, and C++. A number of advantages were associated with the switch, including greater student enthusiasm and more usage of the product in semesters following the course than with previous programming languages [32]. In addition, features such as 2D and 3D graphing (surface and contour plots); data analysis and presentation; symbolic, numeric, and graphical solutions; and superior documentation provided students with added value compared to previous packages used. After nine years of teaching with Mathcad, the department still feels that its choice of a package was a sound one. Using the programming features, students learn to study a problem, apply logic in developing a solution, and to check the solution. These fundamental skills are useful in any course and in professional practice. Beyond the programming features, a student has a set of tools that is valuable for documentation and problem solving to meet a variety of needs.

In designing the course for assessment and continuing improvement, a number of course goals have been developed. These are

- be able to apply the fundamentals of Mathcad including numerical and symbolic manipulation in the presentation of engineering solutions
- be able to utilize basic techniques for iteration, conditionals, and branching in solving problems

- be able to create worksheets which read data stored in external files (input), manipulate the data, and write the results to in an external file (output)
- understand vectors and matrices and be able to perform operations on vectors and matrices
- be able to use built-in functions for basic statistical analysis of data
- be able to use graphical tools for data analysis and presentation
- be able to write programs in the Mathcad environment that may involve looping, conditions, matrix operations, and other features as needed.
- understand professional and ethical considerations associated with privacy, truth in software, intellectual property, copyright, license, public domain, and shareware

It was felt that teaching the above goals could best be achieved by organizing the course in a series of weekly "lessons," with each week's lesson focusing on a specific element of the course. Weekly lessons are supported by a weekly assignment, distributed on Wednesday and collected on Friday, and a weekly test taken by students on Friday. Compared to a two to three tests per semester format used in the course in years past, the weekly testing format appears to have had a positive impact on learning [33]. The two-credit-hour course meets three times each week. A one-hour classroom session (generally a lecture) is held on Monday and two laboratory sessions of one hour each are held on Wednesday and Friday. The laboratory format was adopted to help promote a more active learning environment in the course. A list of lessons for the course is presented in Table 2 below.

Table 2. List of Lessons for Computer Applications in Civil and Environmental Engineering Course

Lesson	Topic
1	Course introduction, policies and administration; computer ethics
2	Mathcad basics : variables, operators, expressions, units, and user-defined functions, the Mathcad environment, editing.
3	Symbolic and numerical manipulation, solution presentation, system analysis
4	Flowcharts, simple conditionals and branching – the if function
5	Iteration (range variables) ; Graphing
6	Programming - branching and looping; programming with the if statement
7	Programming with the for statement
8	Programming with while statements
9	Vectors and vector operations, File input and output
10	Programming with vectors
11	More programming with vectors
12	Solving Equations: numerical, symbolic and graphical techniques
13	Presentations and other cool stuff, using Mathcad plots, 3 D graphics – surface and contour plots
14	Creating animated plots, group project and presentations

Reference 32 contains a thorough discussion of the course, including the rationale for changing from C++ to Mathcad in the mid-1990s, a comparison of Mathcad and C++ topics used in previous offerings of the course, a sample of Mathcad code used in a typical assignment, advantages and disadvantages of using Mathcad as a programming language, classroom approaches including emphasis on language-independent algorithms, and student response to the Mathcad course.

INTEGRATION OF PROFESSIONAL AND ETHICAL RESPONSIBILITY

Why Teach Ethics in a Computer Applications Course?

A computer applications and/or computer programming course is an ideal environment for integrating ethics into a civil engineering curriculum. One of the three breadth outcomes in the ASCE Body of Knowledge outcomes model is leadership [2]. The commentary to Outcome 15, which deals with leadership, states

> Leading, in the private and public arena—which differs from and complements managing—requires broad motivation, direction, and communication knowledge and skills. Attitudes generally accepted as being conducive to leadership include commitment, confidence, curiosity, entrepreneurship, high expectations, honesty, integrity, judgment, persistence, positiveness, and sensitivity. Desirable behaviors of leaders, which can be taught and learned, include earning trust, trusting others, formulating and articulating vision, communication, rational thinking, openness, consistency, commitment to organizational values, and discretion with sensitive information. [2]

The importance of attitudes and behaviors such as honesty, integrity, and earning trust to the role of leadership in a professional civil engineer cannot be overstated. Honoring license agreements, respecting privacy, truth in software (delivering a reliable and accurate product), and paying a fair price for intellectual property are all part of the professional and ethical responsibility that distinguishes an effective leader in an engineering office.

What Concepts are Taught?

In developing a module for presenting computer ethics, codes of conduct adopted by various computer-related organizations were consulted. A current website with links for many of these organizations may be found at http://courses.cs.vt.edu/~cs3604/lib/WorldCodes/WorldCodes.html#world. Included on this website is the Software Engineering Code of Ethics and Professional Practice recommended by the ACM/IEEE-CS Joint Task Force on Software Engineering Ethics and Professional Practices, an excellent and thorough code for constructing course modules. Many colleges and universities have computer use policies, and some of these are also included on this site.

Below is a list of topics discussed in the module for the Computer Applications in Civil and Environmental Engineering Course.

- Privacy – misuse of sensitive data belonging to companies, institutions, and individuals; programmer's responsibility for protecting privacy
- Truth in Software – responsibility for designing and testing custom computer applications for reliability and accuracy; responsibility to users of custom computer applications such as defining the limits of an application and providing updates when errors are discovered
- Intellectual Property – Ownership and license agreements of software; responsibilities of software users to the owner
- Important Software Terms – copyright, license agreement, public domain, shareware

How is the Computer Ethics Module Taught?

In the early years following the development of the computer ethics module, the module was taught by traditional lecture. Following the lecture, the professor provided a handout to reinforce the concepts. During this same time period, the authors were experimenting with team-teaching in a computer applications course. Each author taught

one of the two sections and served as a voluntary second instructor in the other section. This was originally done so that when questions or problems arose in the computer laboratory, one professor could address the problem while the other professor continued teaching the class. This significantly reduced the number of interruptions and helped students from falling behind when they encountered problems. Over the years, students have often voiced their appreciation of the dual-professor system in student evaluations.

It should be noted that another distinct advantage of team-teaching is the assistance available from peers in improving the course. Prior to developing the formal procedures summarized in the section entitled "Course Assessment and Improvement," the authors met weekly to discuss strategies for teaching, testing, creating homework assignments, and making improvements in the course. During one of these meetings it was noted that during the computer ethics module students showed little enthusiasm for what was one of the first lessons of the semester. It was concluded that changing the delivery mode from a lecture where the second professor was rarely involved to an active learning environment with both professors involved would boost enthusiasm and learning.

The resulting module involved assigning students to groups and one of the professors providing a scenario involving computer usage to each student group. The scenarios were designed around the concepts discussed in the previous section and usually asked students to decide if a certain action was appropriate. After hearing all the scenarios, each group had to discuss the scenario and determine what action it would recommend. The other professor served as the "authority" when groups reported on their recommended action. It was not unusual for the discussion of each scenario to be lively, with comments being offered from students in and out of the group addressing the scenario.

As the department responded to the EC 2000 criteria, it began developing a more formal way to document assessment. The current procedures are summarized in a previous section entitled "Course Assessment and Improvement." Upon completion of each course, a professor performs an assessment based on how well the course goals were achieved. Part of the assessment is to make suggestions for improving the course. These suggestions are monitored by an assessment committee, which keeps up with which items have been completed and which items will be carried forward to another year.

One of the recent suggestions for improvement in the Computer Applications class was to develop a way to measure the accomplishment of the goal addressing professional and ethical responsibility. The computer ethics module was taught in the short first week of class along with other introductory information and no direct measurement had been made in previous offerings. Because the classes are coordinated to accommodate team-teaching, the professors met to address the assessment item.

For all topics of the computer applications course except the ethics module the authors have been very pleased by giving the weekly tests focused on the material from that week's module [33]. It was decided to change the computer ethics module slightly by incorporating a pre-test and a post-test, in an effort to assess the effectiveness of the module. Active groups and discussion are still used following the pre-test. The same test was given for both the pre- and post-test. The students did not put their name on either test and were encouraged to respond as they would truly act, rather than give the answer that they thought was hoped for by the professors. The test given in Fall 2004 and the students' responses are shown in Table 3. In addition to topics indicated in Table 3, other scenarios (e.g., privacy issues) are discussed as time allows. Students receive a handout outlining key concepts from the module and are responsible for them on the next week's test.

Results

The pre-test provided insight to the students' awareness of various legal requirements and their interpretation and implementation of that knowledge to make ethical decisions. The impact of the ethics module was evaluated by measuring the change in the average student responses from the pre-test to the post-test. The average of the student responses for each question on the pre-test and post-test are presented in Table 4 along with the change from the pretest to the post-test. The average responses in Table 4 may be recast in the available responses on the test as: 5 — Definitely, 4 — Probably so, 3 — Not Sure, 2 — Don't Think so, 1 — Absolutely not. In Table 5, the average deviation from the correct response (average error) is presented. This deviation is determined by the number of responses to the left or right of the correct response. In all cases the correct answer was at the left or right end of the list of the available responses. A correct response has a deviation of zero and the most incorrect has

Table 3. Pre-test and Post Test on Computer and Software Utilization

1. You worked for your father's company this summer using a computer with MS Office 2003 (the latest version) and really like the package. Your folks bought a new computer for you to bring back to school which came with MS Works (the Home user productivity package) instead of MS Office. The company has a site license for MS Office. Is it O.K. for you to load Office 2003 on your new machine?

	Definitely		Probably so		Not Sure		Don't think so		Absolutely not	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sec 01	0	0	4	2	2	0	8	3	8	17
Sec 02	2	1	2	0	2	1	11	0	4	19

Comments:

2. You have downloaded a game this summer that is a great "first person shooter" that supports multiplayer teams on the network. It is a shareware product. Can you distribute the game to your friends in the barracks for some "study break recreation"?

	Definitely		Probably so		Not Sure		Don't think so		Absolutely not	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sec 01	7	16	10	5	4	0	1	1	0	0
Sec 02	9	21	9	0	1	0	1	0	1	0

Comments:

3. Last year a classmate purchased Mathcad at the Cadet Store. Over the summer he switched majors. You know that the program is of limited use even with the new financial functions and he never really used it anyway. Should you ask to borrow the CDs?

	Definitely		Probably so		Not Sure		Don't think so		Absolutely not	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sec 01	3	9	6	1	3	0	6	3	3	9
Sec 02	7	2	5	1	1	0	7	0	1	18

Comments:

4. You have been assigned a special programming project for CIVL 209. For this project you are told to treat the project as though you are working in an engineering firm: provide a short set of instructions for use, documented examples, etc. The program itself was easy. You spent a great deal of time on the documentation (50% of the grade). As you are about to turn it in you discover that your program gives erroneous results for an odd combination of inputs. If you try to locate and correct the problem, you face a minimum 15 % penalty for a late submission. Do you turn the program in now?

	Definitely		Probably so		Not Sure		Don't think so		Absolutely not	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Sec 01	5	2	5	5	2	2	5	3	5	10
Sec 02	2	0	2	1	6	1	6	3	5	16

Comments:

a deviation of four. The RMS of the deviations, also presented in Table 5, was calculated to evaluate the scatter in the responses. Although some say that ethical issues cannot always be reduced to absolute right or wrong answers, the questions posed to the students do have correct and incorrect responses. Students' ethics came into play when they faced the inevitable dilemma of making the right choice or the most personally advantageous choice.

Improvement was indicated for all cases by the reduced values for the average deviation shown in Table 5. One of the cases showed a reduction of only 5% while the seven remaining cases showed substantial changes ranged from 32% to 100%. Further supporting an improvement is the 20-100% reduction in the RMS of the deviations from the correct response shown for seven of eight cases indicating a more tightly clustered set of responses.

It was evident that the Section 01 responses to Question 3 were very different from Section 02. During the discussion with the students in Section 01 before and after the post-test it was very clear that confusion was regarding the wording or intention of Question 3.

Table 4. Average of student responses

	Average Response			
Question 1	Pre	Post	Change	
Negative shift is desirable	2.09	1.41	-0.68	-33%
	2.38	1.29	-1.10	-46%
Question 2	Pre	Post	Change	
Positive shift is desirable	4.05	4.76	0.72	18%
	4.14	5.00	0.86	21%
Question 3	Pre	Post	Change	
Negative shift is desirable	3.00	2.91	-0.09	-3%
	3.48	1.52	-1.95	-56%
Question 4	Pre	Post	Change	
Negative shift is desirable	3.00	2.36	-0.64	-21%
	2.52	1.38	-1.14	-45%

Discussion of Results

The responses to Question 1 indicated most students had a reasonably good awareness for license restrictions by the overwhelming: "Don't think" so, when asked if they should take a company copy of software back to school.

Table 5. The Deviations from correct.

	Average "Deviation"				RMS "Deviation"			
	Pre	Post	Change		Pre	Post	Change	
Question 1	1.09	0.41	-0.68	-63%	1.54	0.98	-0.56	-36%
	1.38	0.29	-1.10	-79%	1.81	0.98	-0.84	-46%
	Pre	Post	Change		Pre	Post	Change	
Question 2	0.95	0.24	-0.72	-75%	1.26	0.49	-0.77	-61%
	0.86	0.00	-0.86	-100%	1.35	0.00	-1.35	-100%
	Pre	Post	Change		Pre	Post	Change	
Question 3	2.00	1.91	-0.09	-5%	2.39	2.66	0.27	11%
	2.48	0.52	-1.95	-79%	2.83	1.40	-1.43	-51%
	Pre	Post	Change		Pre	Post	Change	
Question 4	2.00	1.36	-0.64	-32%	2.50	2.00	-0.50	-20%
	1.52	0.38	-1.14	-75%	1.95	0.87	-1.08	-55%
A negative shift from the pre-test to the post-test in the values is desirable								

Students were quite confident that redistribution of the shareware game would probably be fine. There was some misunderstanding about some details of shareware licenses and the distinction between shareware and freeware. A student raised an interesting question during the discussion of Question 2 about the applicability of the college policy on "acceptable use" of computing resources.

The more ethically challenging situations arose in Questions 3 and 4. The desire to save the $130 cost of the software lead many of the students to try to stretch the wording of Question 3 to permit "borrowing" the CD. In the end they understood and agreed that the license could be transferred under certain conditions, and that it was unacceptable for two installations from the same license to coexist. The only significant written comments on the post-test were made by students in Section 01 "rewording" Question 3 to explain their answer.

It was most interesting to observe the students' struggle with the issues in Question 4. There was vigorous debate among the students about the conflicting pressure to do what they thought was right and to do what they thought would protect their grade.

Concluding Comments

A computer applications course is well-suited for introducing professional and ethical responsibility to students. Ethics modules that can be developed for a computer applications course are analogous to the principles of effective leadership that are a desirable part of civil engineering education and professional practice. For the module described in this paper, team-teaching played an important role in providing understanding and enthusiasm on the part of the students and helped facilitate the course assessment process.

The authors were well pleased with this first formal effort to measure the improvement in students' understanding of some professional and ethical issues in computer applications. Comparison of pre- and post-test results indicates that the module was effective in promoting student understanding. Also gratifying was the development of a measurable means of documenting the departmental efforts focused on ABET Criterion 3(f). The confusion over Question 3 was another reminder for faculty to consider carefully the potential impact that details in wording can have in almost any classroom endeavor. This requires a careful review of examples and license agreements to ensure that the points to be made are verifiable by the students when they decide to "check things out on their own."

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