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Changes in Student Confidence Resulting from Instruction with Modules on EC 2000 Skills

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Abstract

EC 2000 requires that engineering programs demonstrate that their graduates have acquired the set of skills identified in Criteria 3 (a)-(k). Because of a scarcity of instructional material on many of these topics, a team of engineering faculty members developed a set of short modules for teaching several of them. The modules, which contain learning objectives, a justification, student exercises and assignments, and an instructor's guide, require three 50-minute class periods and can be integrated into a standard engineering course. We tested each module in a classroom setting with a diverse group of engineering students. Using before and after module surveys, the students indicated their agreement with statements concerning their confidence in their ability to do specific tasks derived from the module's learning objectives using a five-point scale (1 for "Strongly Disagree" to 5 for "Strongly Agree"). We also obtained analogous data with a control group not involved in the instruction. In 13 of the 15 modules, the data showed an improvement in the students' confidence to perform these tasks as a result of the instruction. The average improvement was approximately 0.50, indicating that, on the average, one-half of the students indicated an increase in their confidence to do these tasks.

Introduction

The EC 2000 criteria require that engineering curricula teach the set of skills defined in Criterion 3 (a) – (k) [1]. This includes the traditional knowledge of the discipline (i.e., the content) along with the processes needed to use the content (i.e., the processing skills). Engineering programs must demonstrate that their graduates have learned the traditional skills (e. g., design, problem solving, and computational skills) and nontraditional skills (e. g., communication, ethics, and lifelong learning skills). Learning these processing skills requires that a student acquire an awareness of the process (knowledge), experience with the process (ability), and judgment in using the process (expertness). For example, design skill involves knowledge, ability, and expertness in the design process.

Students do not learn processing skills merely by observing the instructor using them, by watching other students use them, or by using them repeatedly in homework assignments without feedback[2]. Since interactive skills cannot be learned by observation, instructors must explicitly teach them and provide considerable supervised practice in their use [3]. In discussing the teaching of engineering ethics, Pfatteicher[4] suggested that instruction must be provided to all students, appear more than once in the curriculum, allow sufficient time for reflection, and be integrated with technical courses. It is natural to extend these constraints to the teaching of all skills.

Students have difficulty transferring skills from stand-alone courses to other areas, e.g., transferring writing skills from English composition or even technical writing to engineering lab courses. They often cannot apply the skills in other contexts [2]. Teaching skills as a part of a conventional engineering course reduces the transferring problem, but learning new skills concurrently with new content, e.g., teaching design methodology along with electronics can confuse students, and so they learn neither well. Research on problem-solving skills showed that students did not acquire this skill by watching faculty and other students work problems or by working many problems (even open-ended problems) themselves [2]. This research showed that problem-solving skills can be taught and learned in a workshop environment where the process is taught separately and then integrated with the course content using a three-step approach: (1) build the skill using context-independent exercises; (2) bridge the skill using simplified problems in target subject domain; and (3) extend the skill to realistic problems in subject courses.

Seat and Lord [3], in discussing interactive skills said that they should be taught in engineering courses as a part of the class material and that the involvement of engineering faculty legitimizes the importance of learning the skill. Woods and his colleagues [5], in discussing ideas for teaching skills, suggested that the instructor should:

- Explicitly identify the skill and explicitly teach it;
- Use a workshop or cooperative learning format;
- Include several opportunities to practice the skill;
- Provide feedback—serve as a coach;
- Encourage students to monitor and reflect on learning;
- Include discussion activities.

Engineering instructors who decide to teach processing skills using these approaches confront four problems:

- Lack of experience and training in teaching skills;
- Need for an interactive teaching style;
- Limited availability of instructional material;
- Need to integrate the instruction into an existing engineering course.

Short instructional modules organized in a workshop or interactive format can meet this need. A team of engineering faculty members has developed a set of fifteen instructional modules for teaching several skills identified in EC 2000 Criteria 3 (a)-(k).

Module Description

In developing the modules, we designed them to fit within a week of classes (i.e., three 50-minute class periods) in upper-level engineering courses. To increase the effectiveness and appeal of the modules, we incorporated active/cooperative learning and the use of web-based resources. In addition to the standard instructional material, each module contained learning objectives, a justification, student exercises and assignments, and an instructor's guide discussing the use of the material and the grading of student work so that an instructor can use the material with a small amount of preparation time.

The skills were grouped into four categories as shown in Table 1. The fifteen modules are available on the web site at ece.ua.edu/faculty/rpimmel/public_html/ec2000-modules. In the following discussion, we will cite examples from the five modules that the three authors of this paper developed. These modules deal with computational skills in the technical area, with oral communication skills in the communications area, project management skills in the professional area, and ethical interpretation and global and societal impact skills in the ethical-societal area.

Table 1. Instructional modules subdivided by skill category

Technical Skills	***Professional Skills***	***Communication Skills***	***Ethical-Societal Skills***
Computational	Project Management	Graphical	Contemporary Issues
Design	Lifelong Learning	Oral Communication	Ethical Interpretation
Experimental	Teaming	Written Communication	Global-Societal Impact
Modeling	Time Management		
Problem Solving			

Instructional Content: Using only three 50-minute sessions for each module forced a less than comprehensive presentation and required that we carefully select the module material. For example in the project management module, the first session contained slides on learning objectives, justification of the material, an introduction to project planning and management with two short team exercises, and managing time and resources with two short team exercises. The second session introduced two project management tools: the work breakdown structure and the linear responsibility chart with an extended team activity on each. The third session continued with two additional tools: the activity network and the Gantt chart with an extended team activity on each. The module did deal briefly with other tools and ideas of project management, but they clearly were supplementary material and were associated with a "secondary" learning objective.

As a second example of selecting material, the three sessions in the ethical interpretation module explored two ethical case studies and developed a professional code of ethics using student input. Students were shown the necessity for ethical behavior and the concepts which govern ethics. Through class consensus (and without reference to existing professional codes of ethics), the students then developed their own code of professional ethics enumerating the engineer's ethical responsibilities to society, to his or her employer, to fellow workers, and to himself or herself. The students' code was then compared with the codes developed by professional engineering societies. This comparison served three purposes: (1) it made the students aware of the professional society codes and showed them where they can obtain the codes, (2) it illustrated common themes among the various professional codes, and (3) it allowed the instructor to demonstrate that the codes do not cover all possible situations and that additional resources, such as ethics hotlines, exist for these situations. The instructor then showed the students how to find these additional resources.

Designing some of the technical modules presented a little different problem because most of the students had a significant exposure to some of the material in a prior course. For example, most students had a course dealing with computation in some form and so the computational module needed to provide a short introduction or review but then focus on some applied aspect not usually treated in the introductory course. In this module, we reviewed Matlab and some computations using this tool and then focused on developing algorithms as a fundamental skill, and computational accuracy as the advanced applied concept.

Active and Cooperative Learning Emphasis: With the emphasis on active/cooperative learning techniques, the classroom material typically contained short mini-lectures describing some established ideas followed by team exercises with students reporting to the entire class as a part of the exercise. This approach provides some instruction in the skill, followed by a chance to practice it, followed by a chance to see and evaluate other student's efforts and to have their work evaluated both by students and the instructor -- all important steps in learning a skill [3, 4]. However, team exercises took many forms in the different modules and a few examples are described in the next few paragraphs.

In the introductory session of the computational module, students were asked to analyze a simple physical problem (a tank filling problem was used), to write the Matlab expressions to plot a function, and to use the online help material to determine how to do a new task. In the second session, which dealt with algorithm development, students worked in teams of three to develop step-by-step procedures to compute the area of a flat component. Individually they developed an algorithm to calculate the mean and variance of 10,000 data points and, then wrote the Matlab instructions implementing their algorithm. In the final session on accuracy, they simulated the solution to a differential equation, made a list of possible sources of inaccuracy, and selected a step size to obtain a specific level of accuracy.

Student activities in the ethical interpretation module dealt with four items. The first considers the case of the Ford Pinto where a design flaw allowed the gas tank to rupture in certain types of collisions. The students answered a series of questions, discussed general ethical issues and ethical issues arising from the case, determined the need for an engineering code of ethics, and drew conclusions. With this basis (and their prior personal experiences) they developed a code of engineering ethics, determined key elements within an engineering code of ethics, and combined elements from each group's codes to produce a single, refined code for the class. After the refined code of ethics had been developed, they compared it to two codes of ethics developed by professional organizations (e. g., IEEE, ASME, ACS, ASCE, ACM, and NSPE) and discussed strengths and weaknesses of class's refined code and each of the two established codes of ethics reviewed. Finally, they studied the case of Wernher von Braun and considered his association with the Nazis during World War II and his role in the development of the US rocket technology. They answered a series of questions, discussed ethical issues arising from the case, and drew conclusions.

<u>Instructor's Guides:</u> Since many engineering instructors will find that teaching these new skills and grading the associated student work is a new and perhaps frightening experience, we have included detailed instructor's guides with each module. These provide important information to assist an inexperienced teacher in using the material. Generally they provide tips on using the instructional material, making homework assignments, grading student work, and assessing improvement in the students' skill level – all intended to reduce the instructor's preparation time.

Grading homework in many of these modules is difficult because the answers usually are verbal and subjective with no single right answer. The project management module's guide suggests that when grading problems that ask for a definition, list, or process, the instructor should grade for responsiveness (Does the answer address the question?), reasonableness (Does answer make sense?), and completeness (Does answer include a complete response to the question?). Also, when the question requires that the student consult a web site or a printed reference, the instructor should evaluate the appropriateness of the reference and the completeness of its citation. Basically, these grading criteria enable the instructor to determine if the student read the question, visited the web site(s) or reference material, read the material, thought about it, and constructed an appropriate response.

Grading problems that ask students to complete an analysis or synthesis task also requires the use of subjective criteria. The instructor should determine if the submitted work dealt with the assigned project in a reasonable and complete way, if it has the correct format, and if it is presented in an understandable style. Several of the modules recommend that the instructor give a list of these criteria to the students when he or she makes the assignment. The key is to get the students to recognize, generate and document good solutions to the assigned problem and to give them feedback on how well they did this. Knowing exactly what the instructor expects will encourage the students to follow the guidelines for a good result.

Evaluation Study

In an evaluation program, we taught each module in a classroom setting with a faculty member, other than the developer, as teacher. The modules were taught during a standard 50-minute period on a Monday, Wednesday, and Friday schedule to ten or so students. Students receiving the instruction, referred to as the "experimental group", completed several evaluation forms prior to the start of the module and at the end of the module. In addition, we collected data on a second group of students, a "control group", who were similar to the experimental group but did not receive the instruction. Both groups were randomly selected from a group of paid volunteers after screening for schedule conflicts. The overall group contained majors from most engineering disciplines with 65 % seniors, 25 % juniors, and 10 % sophomores. In this population, 45 % had a GPA above 3.0 while 55 % had one between 2.0 and 3.0, and 61 % had one or more coop or intern experiences, while 39 % had none. In response to a question about their formal training in the module topic, 48 % indicated that they had no experience, 36 % indicated experience in one or two classes, and 16 % indicated experience in three or more classes.

Using a survey form, we asked the students to assess their confidence in their ability to complete tasks representative of the module's learning objectives and to indicate their confidence using a five-valued scale (i.e., 1 -- "Strongly Disagree", 2 -- "Disagree", 3 -- "Neutral", 4 -- "Agree", and 5 -- "Strongly Agree"). In creating this list of tasks, we converted each learning objective into one and only one task statement so that there was a one-to-one correspondence between the modules' learning objectives and students' confidence statements. For example, the objective, "Students should be able to write guidelines for an effective presentation" became "I am confident that I can write guidelines for an effective presentation." A companion paper describes data from a second survey in which the students evaluated the appropriateness, effectiveness, and completeness of the modules [6].

In the study, we collected post-module data for all modules; control data for all but the modeling module; and pre-module data for all but the first four modules we taught (global and societal impact, lifelong learning, oral communication, and project management modules). We averaged the student responses for each task and we will refer to this average as a "confidence score". We then computed the mean value of the confidence scores for all task statements in each module to obtain an average module confidence score (e. g., a confidence score for the teaming module). Finally, we computed the mean value of the average module confidence scores in each skill area to obtain an average area confidence score (e. g., a confidence score for the communication area).

Evaluation Results

Figure 1 shows the average pre-module, post-module, and control confidence scores for each of the fifteen modules. Differences between pre- and post-module scores ranged from zero to 0.87 with a mean value of 0.49; while differences between control and post-module scores ranged from 0.02 to 1.39 with mean value 0.53. Mean differences near 0.5 indicate that, on the average, one-half of the students selected a higher value in accessing their confidence in their ability to perform the task after completing the modules. Modules showing the largest improvement (i.e., those with a difference greater than two-thirds) were the modules on design, problem solving, project management, teaming, contemporary issues, and ethical interpretation skills. Modules showing the smallest improvement (i.e., those with differences less then one-third) were the modules on computational, experimental, lifelong learning, graphical communication, and written communication skills.

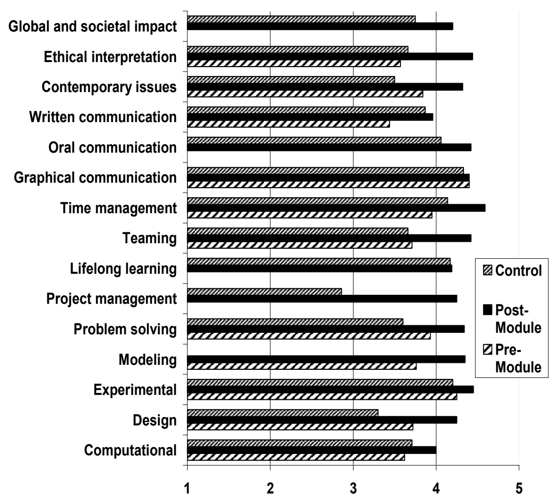

Figure 1. Average module confidence scores for the fifteen modules

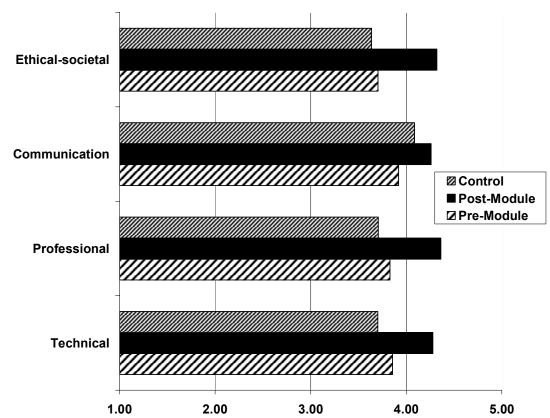

Figure 2. Average area confidence scores

Examining the baseline data, that is the pre-module and control data, allowed us to get an overall impression of our students' confidence in their ability to do this assortment of tasks and to identify the areas where they had the most and least confidence in the ability. The average of the pre-module and control scores were 3.86 and 3.75, suggesting (but not proving) little or no difference in the student population in the experimental and control groups. The overall baseline average (the average of the pre-module and control data) was 3.80. This mean value suggests that, on the average, 80 % of the students "agreed" that they had confidence in their ability to compete the identified tasks*,* while 20 % did not "agree", that is selected the next lowest value (i.e., "Neutral"). We saw only small differences between the baseline confidence scores in the four areas with scores of 3.78 in the technical area, 3.77 in the professional area, 4.00 in the communications area, and 3.67 in the ethical-societal area. When looking at individual modules, the data showed that the modules that had baseline confidence scores greater than 4.0 dealt with experimental, lifelong learning, time management, graphical communication, and oral communication skills. Only the module on project management skills had a baseline score less that 3.0; the others were in the range 3.5 to 3.75.

Figure 2 shows the average area confidence scores for the four skill areas defined in Table 1. These data show that our students reported larger improvements in their confidence to do tasks associated with professional and ethical-societal skills with differences between pre- and post-module values of 0.53 and 0.62, respectively, and a smaller improvement in their confidence to do tasks associated with technical and communication skills where the differences were 0.42 and 0.34, respectively. These finding may suggest that the students believed that the existing curriculum provided a better preparation in the technical and communication skills than in the professional and ethical-societal skills.

Figure 3 shows the confidence scores for the computational module. In general, these data show small differences between control and post-module confidence scores with values ranging from 0.2 to 0.4, indicating that 20 to 40 % of the students selected a higher value for their confidence in their ability to do these tasks after completing the module.

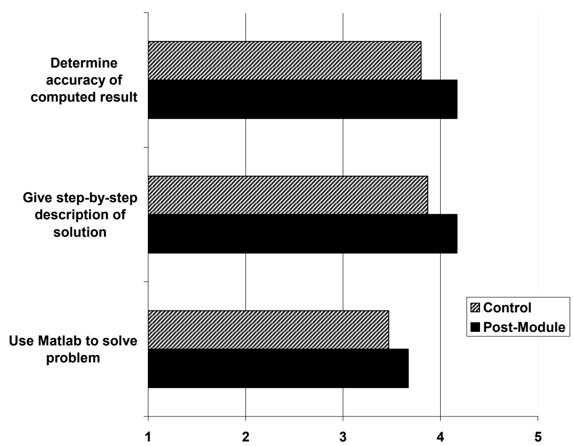

Figure 3. Confidence scores for computational module

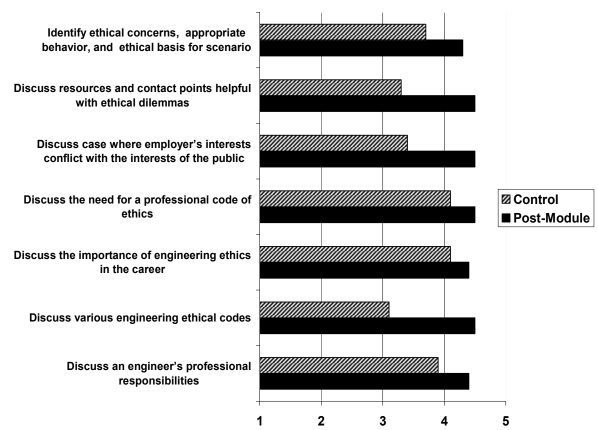

Figure 4. Confidence scores for the ethical interpretation module

Figure 4 shows the confidence scores for the ethical interpretation module. In general these data show substantial differences between control and post-module scores. All were greater than 0.3 and three of the seven were greater than 1.0; the mean difference was 0.79. This mean difference indicates that about 80 % of the students selected a higher value in defining their confidence to do the tasks associated with ethical interpretation skills.

Figure 5 shows the confidence scores for the global and societal impact module. In general these data show a substantial difference in the students' confidence to complete task in this area. The mean difference was 0.45, but two tasks (those dealing with reference material) showed no difference while two (preparing a report and identifying regulatory bodies and regulations) showed differences near 1.0.

Figure 6 shows the confidence scores for the oral presentation module. These data show a modest difference between the post-module and control scores. The mean difference is 0.36, implying that, on the average, about one-third of the students selected a higher value after completing the module. The largest difference occurred with the evaluation and critique task and the lowest values with the writing guidelines and preparing a talk task.

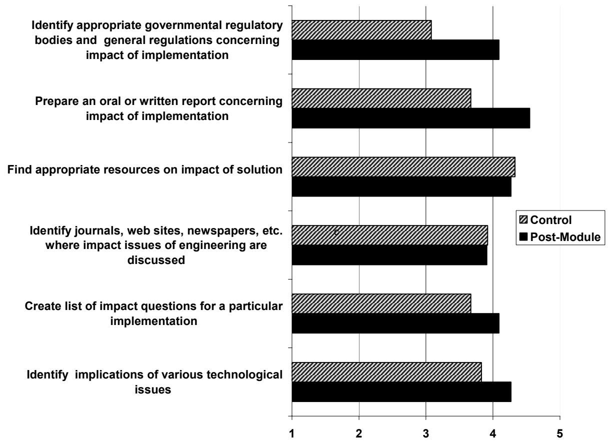

Figure 5. Confidence scores for the global and societal impact module

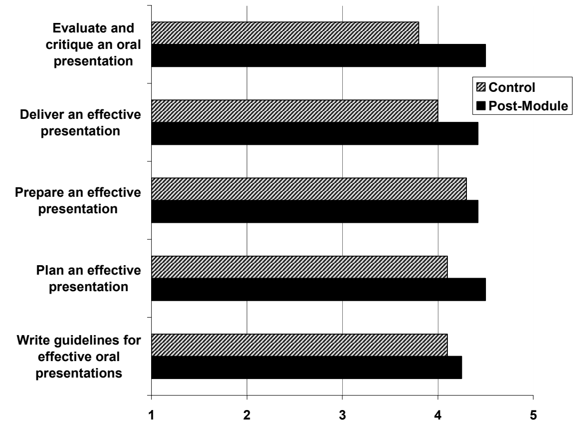

Figure 6. Confidence scores for the oral presentation module

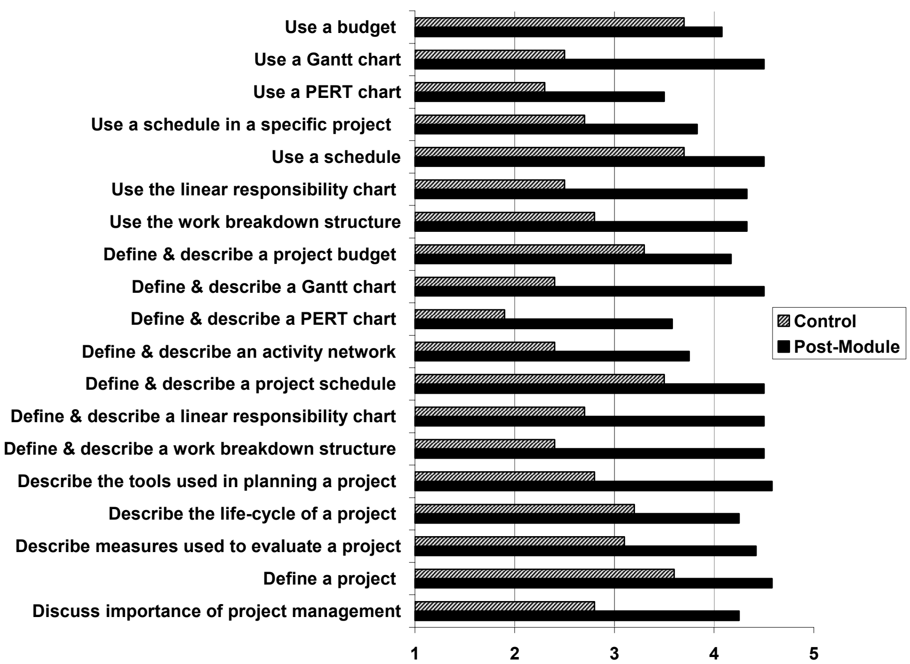

Figure 7. Confidence scores for the project management module

Figure 7 shows the confidence scores for the project management module. Data for this module show the largest differences between the control and post-module scores of all the modules. The mean difference was 1.39 implying that, on the average, 40 % of the students picked two values higher on the confidence scale while 60 % picked one value higher after the module.

Conclusions

The observed mean increase in post-module confidence scores (approximately 0.5) implied that, on the average, one-half of the students increased their confidence rating by one value on a five-valued scale as a result of the instruction in the module. We do acknowledge that student confidence may not be the most reliable indicator of learning, but it is widely used and does provide a convenient measure with some validity (for example, see Felder et. al. [7]). We believe that since the pre- and post- module surveys were only one week apart, the effects of temporal variations were minimized. Also the similarity between the pre-module data and the control data, which was obtained from different sets of students, give some credence to the measures. We believe that instruction with these modules increased our students' learning in a broad set of skills derived form Criterion 3 in EC2000 [1].

Acknowledgement

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Reference

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Biographical Sketches

Russell Pimmel is a Professor in the Department of Electrical and Computer Engineering at the University of Alabama. He earned his undergraduate degree in Electrical Engineering at St. Louis University. His M.S. and Ph.D. degrees are from Iowa State University in the same field. His research concerns neural networks and computer architecture. At the University, he teaches digital system and computer architecture, and capstone design.

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