Preparing for Professional Practice in Industrial Engineering: A Complementary Capstone Experience Influenced by the EC2000 Outcomes

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Introduction

The “EC2000” learning outcomes are currently receiving a great deal of attention within the engineering education community. EC2000 (or Engineering Criteria 2000) refers to a set of eleven skills and abilities expected of graduating engineering students (ABET, 2001). In order for an engineering school to be accredited by the US Accreditation Board for Engineering and Technology (ABET), the school must provide assessment results showing that its graduates have mastered these skills and abilities captured in the EC2000. This implies, in turn, that engineering programs must ensure that these skills and abilities are part of their students’ educational experiences.

Given the need to ensure that the EC2000 learning outcomes are adequately addressed in student experiences, the following types of questions can arise: Are the learning outcomes adequately addressed in our existing courses? Can coverage of the outcomes be integrated into the existing courses? Will new learning experiences be required? What additional types of learning experiences do we need to provide?

This paper focuses on one approach to answering these questions taken in the Industrial Engineering Department at the University of Washington. Specifically, the EC2000 learning outcomes were used as a tool in developing a “complementary capstone experience.” The goal of this experience, as with other capstone experiences (e.g., Todd et al., 1995), was to support students’ transition into professional practice. Specifically, the course provided students with an opportunity to discuss what it means to be a professional engineering practitioner and to use ideas from this discussion to synthesize and extend knowledge acquired in earlier courses. The course was intended to complement the efforts of traditional capstone (senior design) experiences. This work builds on earlier work we completed in this area (Atman et al., 1999).

In this paper, we describe the design and evaluation of the course. We believe that the course represents a new type of valuable learning experience for our students. We also believe that the insights we gained from teaching the course, and the materials developed for it, may be valuable for other efforts to address the EC2000 learning outcomes.

Professional Practice Issues in Industrial Engineering: A Complementary Capstone Experience

The idea for the complementary capstone experience stemmed from the observation of a mismatch between what we hope will occur as a student moves through an engineering curriculum and what traditionally occurs. In the traditional engineering program, students spend a great deal of time in classes focused on technical knowledge. Additionally, as students go through their curriculum, they are likely learning about engineering activity in work settings and gaining experience with what it means to be a professional engineering practitioner.

In engineering education, we hope that students will integrate the knowledge from these experiences into a coherent understanding of what it means to be a professional engineering practitioner (Bordogna et al., 1993; Atman et al., 1999). However, given that little time is spent helping students develop a model of what it means to be an engineering professional, it seems quite likely that students fail to integrate their knowledge as sufficiently as we might hope. This may be evidenced by the types of industry complaints described in various reports on engineering education (e.g., ASEE, 1994).

These observations suggest that a valuable culminating learning experience would be one that would help students to:

- Develop a Model of a Professional Engineering Practitioner. The experience would help students to acquire a model of what it means to be a professional engineering practitioner, and to deeply understand the dimensions of the model.
- Use the Model to Synthesize Prior Knowledge. The experience would help students synthesize previous knowledge and experiences by connecting them to the model of a professional engineering practitioner.
- Use the Model to Understand the Complexities of Real-World Practice. The experience would help students anticipate professional practice activities by connecting the model to features of real world experiences in the engineering discipline.

In the context of these goals, the EC2000 learning outcomes take on a new significance. The EC2000 learning outcomes represent one model of what it means to be a professional engineering practitioner. Although this model is not without shortcomings, there are definite benefits. Because the model comes from ABET and is known throughout the engineering community, it is a shared model. Also, because the model stems from discussions with employers about what they want, it is authentic.

As a result, we decided to use the EC2000 learning outcomes as the model of professional engineering practice for the complementary capstone experience. Additionally, we selected four main instructional strategies for addressing the course goals (as shown in Table 1). These instructional strategies are described below.

Readings: Readings from a variety of sources were used to explore models of professional practice and specific dimensions of being a professional engineering practitioner (i.e., an understanding of ethical responsibility). For example, the paper "Development of Customer-Based Outcome Measures for an Engineering Program" was used in the beginning of the course

Table 1. Mapping between Course Goals and Instructional Strategies

Course Goal	*Readings*	*Interactive Class Activities*	*Project*	*Guest Speakers*
Develop a Model of Professional Engineering Practice	*X*	*X*	*X*	
Use Model to Synthesize Prior Knowledge		*X*	*X*	
Use Model to Connect to Real-World Practice		*X*	*X*	*X*

as we discussed the idea of developing a model of a professional engineering practitioner (Besterfield-Sacre et al., 1997). In this paper, the authors used group affinity diagrams and importance weights to synthesize input from practicing industrial engineering and develop a model of a professional engineering practitioner. The paper helped students to understand how such a model could be developed, and also to see alternatives to the EC2000 model.

Interactive Class Activities: Much of class time was used for interactive in-class activities. A variety of class activities were used to help students think broadly about the meaning of the different EC2000 learning outcomes and to help students make connections between learning outcomes, prior understanding, and real world activity. These activities included an analysis of factors leading to the failure of a team as described in an ethnographic account of that team (Turns, 1998), and analyses of case studies of engineering activity to determine if unethical behavior had occurred.

Guest Speakers: Guest speakers representing a variety of work settings and professional experiences spoke about their career as professional industrial engineering practitioners. Four guest speakers were distributed spread through the term. Each speaker was asked to describe their IE work setting and to give insight into projects on which they have worked. Students were prompted to reflect on the experiences of the guest speakers in terms of the various dimensions of professional practice activity (i.e., the EC2000 learning outcomes).

Design Project: For the term project, students were asked to develop a tool to educate a selected audience about industrial engineering. As part of this project, students were asked to select an interesting work setting and then work out the IE opportunities that could be available in that work setting. The completion of the project was phased, involving submission of individual intermediate deliverables and some class time devoted to design studio. The project culminated with an open house where the students displayed their projects to a variety of participants including the IE faculty and freshman from a freshman design classes. Additional information about the design project, including the schedule of intermediate milestones, is included in appendix 1.

Chronologically, the course opened with a discussion of how to characterize what it means to be a professional engineering practitioner. As the course went on, there was a great deal of interplay among these instructional strategies. Readings and activities meant to explore the scope of industrial engineering knowledge were followed up with a project assignment to identify industrial engineering opportunities in a work context. Then readings and activities to understand specific engineering practitioner dimensions (e.g., lifelong learning, professionalism, and ethics were followed up with a second project assignment to relate these dimensions to the work context and projects identified. The remainder of the term was spent focusing on the completion of the projects and the preparation for the final exam.

Evaluation Approach:

The complementary capstone experience, "Professional Practice Issues in Industrial Engineering," was taught in the spring of 2000 to an enrollment of twenty-one students. As part of a formative evaluation of the course, we gathered a variety of types of data. First, we retained *copies* of class activity products, student project work, and their exam (for exam questions, see

Appendix 2). Second, using an end-of-term *survey*, we asked students to rate each instructional activity and class topic on each of the following dimensions: did they like it, did it get them to think, did they learn from it, did it prepare them for their job, and was it worthwhile. Additionally, in this survey, we collected qualitative *open-ended comments* from students. Finally, we kept a *record of observations* throughout the term.

Ideally, our evaluation of the course would focus on the question, "Did it work?" Based on the ideas used to develop this course, we would consider that the course "worked" if students were better prepared to enter professional practice. At this early stage, such data is not available. Therefore, we focused our initial evaluation on the three questions shown below:

1. <u>Did students achieve the learning objectives for the course</u>? The four-question exam tested students relative to specific learning outcomes of the course. Successful exam performance by a majority of the students provides evidence that students achieved the learning objectives for the course. Additionally, a distribution of scores on the exam can be used to infer that the material represented an appropriate intellectual challenge.
2. <u>How well did students perform on the project</u>? The project represented a novel project activity for engineering students. Additionally, it was intended to be an important learning vehicle for the students. In essence, we wanted to know how well the project turned out.
3. <u>Did students find the course valuable</u>? Students can be good judges of their own learning needs. If the students found the course valuable, then we can infer that the course satisfied a need.

Selected Evaluation Results

<u>Did students achieve the learning objectives for the course?</u>

Students' scores on that final exam are given in Figure 1. Specifically, the figure shows the average, maximum, and minimum grade for each of the four questions. In addition, standard deviations are used to create error bars that illustrate the deviation in the scores.

These results have several implications. First, these results demonstrate that it is possible to create meaningful exam questions for this type of instructional experience and that such questions can be graded in a way that discriminates among students. Second, the results show that most students performed well on the final exam, although not exceptionally well. The results suggest that there is definitely room for improvement. Finally, the statistical results indicate that the scores on question 3 are significantly lower than the scores on the other questions, which are indistinguishable (statistically) from each other. This finding suggests that the course may not have been as successful in helping students gain a more precise understanding of specific learning outcomes.

<u>How well did students perform on the project?</u>

As mentioned earlier, the overall context of the project was to develop a tool to educate a selected audience about industrial engineering. The project was phased and included four main deliverables – the selection/ description of a possible IE work setting, description of IE

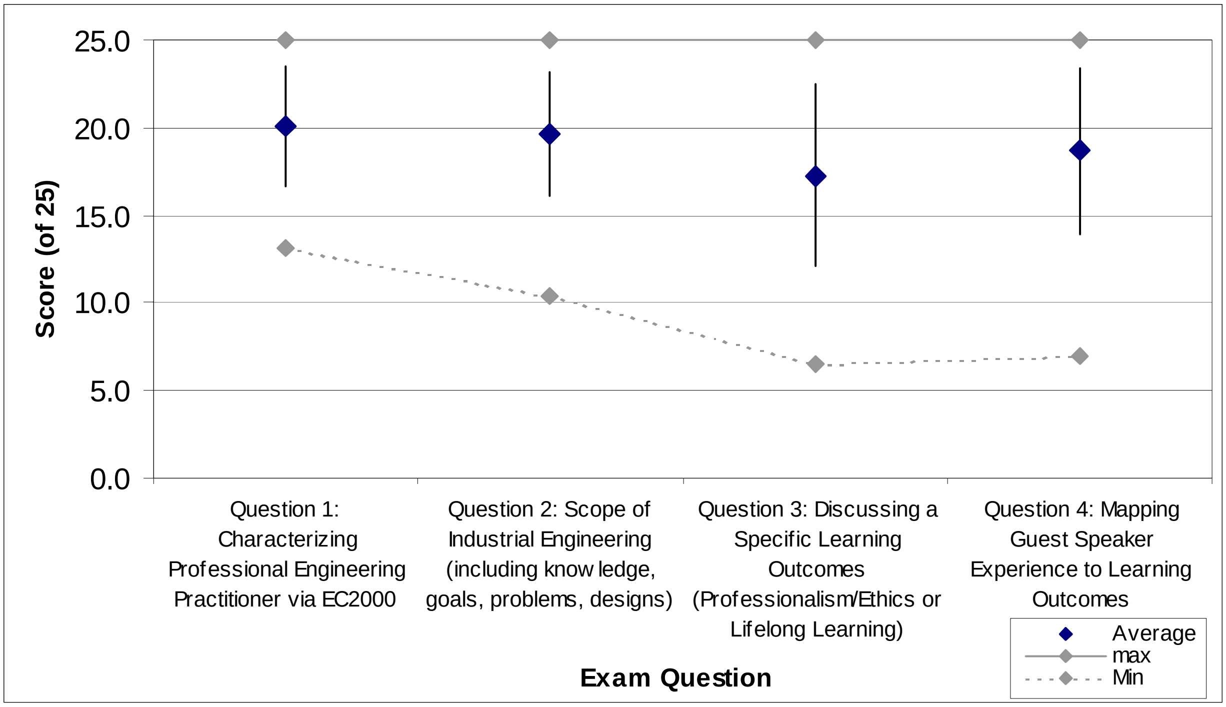

Figure 1. Statistics on Final Exam Grades

opportunities in the work setting, an exploration of the professional practice dimensions associated with projects in the work setting, and the design and delivery of the final educational tool. Of these main activities, the first and last were group activities while the second and third were individual.

The 21 students in the class formed seven groups. These groups identified a variety of different work settings, as the contexts for their project, as shown below. The students were very thorough in describing their work settings. The groups used a variety of strategies for finding information about the work setting including visiting the work setting, interviewing people who work in the setting, and searching the web for information about the company.

- Grocery stores: Albertsons (1), Safeway (2)
- E-Commerce: Amazon (3)
- Leisure: Disneyland (4), Stevens Pass -a local ski resort (5)
- Retail: Good Guys (6)
- Shipping: UPS (7)

In the second graded deliverable, the students were asked to work individually and focus on characterizing the scope of industrial engineering, describing the range of industrial engineering projects possible in their work setting, and describing detailed plans for one possible project. The strengths of these reports included (a) the comprehensiveness of the students' descriptions of the scope of industrial engineering and (b) the completeness with which they developed lists of possible projects within their work settings. The former were surprisingly difficult to grade, while the latter were fun to read and easy to grade. The average grade on this deliverable was a B+.

In the third significant deliverable, the students were again asked to work individually. This time they were asked to focus on characterizing IE problems broadly. Specifically, they were to select a single project for their work setting and describe (a) the project, (b) the professional and ethical dimensions of the project, (c) implications for multidisciplinary teamwork, (d) important global and society considerations, and finally (e) lifelong learning issues. As with the previous deliverable, the average grade was a B+. Most students were able to write meaningful descriptions of these outcomes and to make connections between the outcomes and their project activities.

In the final phase of the project, students were to work in teams, to use their individual milestones as input information, and to develop their educational tool describing IE. Of the groups, one created a website, one created a set of brochures, and the remaining five groups created some variation of a poster. Two of the posters are currently on display in the industrial engineering advising office at the University of Washington. Additionally, the brochures have been handed out to prospective students. Despite this success, the educational tools were disappointing given the amount of information generated by the individual students in their reports. Several students reported that their groups had difficulty synthesizing their information into their educational tool.

<u>Did students find the course valuable?</u>

As part of the evaluation of the course, we asked students to provide overall comments and suggestions. A sampling of these comments is given verbatim below:

> Overall, I enjoyed this class because each topic got me to think about the abilities and roles of IE in professional practice that I could not understand so early if I didn't take the course. Simply put, this class gave me more confidence and reasons for being an IE. I wish the course is being integrated to the introductory level course such as the introduction to manufacturing (IE 237).
>
> As a whole, it is an important class, especially for juniors. So they would have an idea what scope of IE, or even simply what IE is. I would suggest this class would be a requirement class. Activities are fun, I believe they can be improved.
>
> Perhaps this class could be structured around case studies. This would provide more room for discussions and debate, thus making the class more interactive. An example of this would be the case studies on ethics that were done in class. The discussions and debate were lively and enjoyable.
>
> Although I felt the class should have been taught earlier in the curriculum, its hard to do because we need to already have a broad knowledge base within IE. The class was not very challenging, however I learned exactly what you wanted us to, so in that respect, it was an overall good class. I feel a lot more confident about talking to others of my major and have a better understanding of it myself. I wish there could have been some other type of project than the one required to do.

These comments suggest the variety of themes that appeared in the comments as a whole. First, the students perceived the course to have been valuable (even when they expressed frustration with particular elements of the course). Second, the students' opinions were mixed as to when they thought the course should be taught. Several students mentioned that this type of course would have been valuable earlier in the curriculum, in order to help them acquire a better understanding of the goal of their educational process. At least one student (however) acknowledged the tension in such a desire (i.e., "its hard to do because we need to already have a broad knowledge base within IE"). Finally, the students expressed an interest in having more interactive class activities similar to the ones that they had enjoyed.

Discussion

Overall, we feel that this course was a success, particularly as a first offering. The students worked hard, accomplished the goals of the course, and recognized the value of the experience.

We are interested in teaching the course again. When we do, we plan to keep many of the elements of the course the same. For example, we will retain the learning objectives, many of the instructional strategies, and particularly the emphasis on the EC2000 learning outcomes as a model of a professional engineering practitioner. We would probably develop additional interactive class activities, identify some new readings, and make changes to the project assignment in order to address problems that students experienced. Additionally, we will need to address issues that arose in our first offering, such as the overlap with the traditional senior design course.

At the same time, we believe that this research effort has resulted in important outcomes that transcend the course itself. First, the experience provided us an opportunity to develop outcome-centric resources (e.g., resources for teaching ethics, resources for discussing lifelong learning) that can be used to integrate EC2000 outcomes into other contexts. For example, an ethics interactive class activity developed for the course has since been used in two different instructional contexts. Second, this course offering resulted in data concerning students' knowledge and abilities relative to EC2000 outcomes. For example, for the third exam question, many students discussed issues of lifelong learning. Such data is useful not only for accreditation purposes, but also to provide a baseline concerning student understanding in these areas.

Finally, a major outcome of this work has been an illustration of how the EC2000 learning outcomes can be used in a pivotal, constructive role in engineering education. In the pilot course, the learning outcomes ceased to be a guide for accreditation assessment, and became, instead, a roadmap that students could use to gain a deeper understanding of engineering and professional engineering practice. The students themselves expressed a deep interest in this topic. In fact, the topic of "Characteristics of an Engineering Professional" received the highest survey ratings on three of the five dimensions that students rated (i.e., "I enjoyed it," "it got me to think," and "I know more"). We believe that there are important opportunities to be realized with respect to the role of the EC2000 learning outcomes in engineering education. Framed successfully, EC2000 outcomes may provide an opportunity to support the integration of engineering education.

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Appendix 1. Final Exam Questions

1. <u>EC2000 Learning Outcomes - Generally</u>. Imagine that you are in a job interview with an interviewer who has just heard of the EC2000 learning outcomes for the first time. Because you have been in this class, you are now prepared to discuss this topic with the interviewer (and show him/her how much you know). Please provide responses to the following interviewer's questions:
   a) Interviewer: *What exactly are the EC2000 learning outcomes*?
   b) Interviewer: *I have heard that there was a class called "Professional Practice Issues in Industrial Engineering" that was organized around the EC2000 learning outcomes. Why would a professional practice class be organized around the EC2000 learning outcomes*?
   c) Interviewer: *But what about the industrial engineering part… I have seen the list of outcomes and they seem generic across all engineering disciplines. How do these outcomes become specific to industrial engineering*?

2. <u>Scope of Industrial Engineering</u>. In one of your work experiences after graduation, you are asked to join a team consisting of other engineers as well as non-engineers. Because the team leader recognizes that multidisciplinary teams work more effectively when the members appreciate and understand the contributions of each member, the leader invites each member to explain their disciplinary background to the others. In particular, she invites each member to respond to the following questions about their discipline. On you turn, you thus need to explain industrial engineering to your engineering and non-engineering teammates.
   a) What are the goals of industrial engineering?
   b) What types of problems does an industrial engineer typically solve? What types of products and processes do they design?
   c) What types of technical knowledge does an industrial engineer have?
   d) What types of techniques and tools are common in industrial engineering practice?
   e) What engineering disciplines are similar to industrial engineering, and how does IE differ from those engineering disciplines?
   f) What types of disciplines would an industrial engineering typically work with?
   g) Why is industrial engineering an engineering discipline?

3. <u>EC2000 Learning Outcomes – Specifics</u>. As a recent alumni of the UW Department of Industrial Engineering, you have been contacted by a junior level industrial engineering student who wishes to ensure that their IE

preparation is as strong as it can be. At the suggestion of a faculty member, the student has taken a look at the EC2000 learning outcomes and has found that she has some really general questions about two of these outcomes:

(f) An understanding of professional and ethical responsibility,
(i) A recognition of the need for, and an ability to engage in, lifelong learning.

Specifically, the junior has sent the questions listed below. Because the junior recognizes that you are a busy professional, she only asks for your advice on one outcome. As a recent graduate of the program, you empathize with her desire to best prepare herself.

a) Her 1st question: *For one of the outcomes, could you describe broadly what it entails*?
b) Her 2nd question: *Where in the IE curriculum will I encounter this outcome*?
c) Her 3rd question, *How well will the curriculum prepare me relative to this outcome*?
d) Her 4th question, *How could I supplement the required portion of the IE undergraduate education in order to best prepare myself relative to this outcome*?

4. <u>Guest Speaker Experiences and Mapping to Outcomes</u>. As a new employee at company x, you find that you are eager to maintain contact with the University. Your idea is that your company could provide guest speakers to classes at the University of Washington. Furthermore, you think that this should be an easy to coordinate **--** the speakers can talk about any of their work experiences since almost all work experiences can be unpacked to illustrate how the EC2000 learning outcomes are collectively instantiated in the experience.
When you bring the idea to your boss, he thinks it is a good idea (and something he is willing to pay his employees to do) but he needs more information. He asks you to give him something in writing. You then decide that the best way to explain your idea to him is to illustrate the idea by talking about one of the guest speakers in your INDE499C: Professional Practice Issues in Industrial Engineering class.
a) Select one of the guest speakers and describe what he/she talked about.
b) Discuss how the work experiences of the guest speaker illustrate the idea that all of the EC2000 learning outcomes are integrated when it comes to a real work experience.
Discuss how effective you believe the speaker was and what advice you would give your peers who are invited to give talks at the UW.

Appendix 2. Project Description

Industrial engineering practice involves an interplay between industrial engineering knowledge, general engineering practice skills, and the demands and issues associated with specific work settings. Industrial engineering practitioners must understand how to apply their capabilities to the problems in the setting where they work. They need to be able to recognize the types of issues that can and will arise in solving those problems. In addition, industrial engineering practitioners often need to anticipate, recognize, and identify industrial engineering problems that they could solve. The activities of the class project will provide you with an opportunity to practice these types of professional practice thinking.

<u>Project Statement</u>

For this project, you will develop a tool that educates a chosen audience about industrial engineering. Your tool will achieve this goal by describing industrial engineering a specific work setting.

This project has both product and learning goals associated with it. The general learning goal is to prepare you for professional practice. To this end, the project is intended to get you to think about a variety of issues associated with professional practice in industrial engineering. As part of the project, you will be asked to think about (a) the definition of industrial engineering, (b) the mapping between industrial engineering and the opportunities in specific work settings, and (c) a broad set of issues associated with completing industrial engineering projects. In the educational tool that you develop, you will need to include content related to these three areas. You and your team will develop this content through a set of preliminary assignments.

The product of the project will be a tool that educates a chosen audience about industrial engineering. Although you need to ensure that certain content is included in your educational tool (as described in the previous paragraph), many other design decisions will be up to you. Student teams will select the format of the educational tool, contingent upon instructor approval, and determine how to implement this format to best serve the educational goal. Possible formats for the educational tool include:

- a poster for display in the industrial engineering undergraduate advising office,
- a tutorial/case study for the industrial engineering web pages, or
- an exhibit that representatives of the IIE chapter could use when attempting to communicate industrial engineering to K-12 students during Engineer's week.

The project will culminate in a final report, due on the last day of class. The last day of class will be used for an "open house" during which you and your team will present your final project. A variety of people will be invited to attend the open house including the industrial engineering faculty, students from the freshman engineering classes, and the undergraduate advisors from the various engineering programs.

Milestones and Dates:

Table 1. Milestones and Dates Associated with Term Project

Milestone	Date	Who
1. Teams and Work Settings	4/3	Group
2. Work Setting Description	4/10	Group
3. Design Ideas	4/17	Group
4a. IE Problems in a Work Setting - Draft	4/17	Individual
4b. IE Problems in a Work Setting - Final	4/24	Individual
5. Design Studio	5/1	Group
6a. Understanding IE Problems Broadly - Draft	5/10	Individual
6b. Understanding IE Problems Broadly - Final	5/17	Individual
7. Open House Presentation of Product	5/31	Group
8. Final Report on Product	5/31	Group

Your work on this project will be facilitated through a set of milestones - a series of assignments and class activities, completed either individually or in your groups. The table below indicates the nature and date of each milestone (as well as the type of grading associated with each milestone).

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