Teaching Professional and Ethical Aspects of Electrical Engineering to a Large Class

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***Abstract*— As electrical engineering has expanded and diversified with the technology it creates, it has also more firmly established itself as a well-respected profession that has provided significant benefits to society. Electrical engineering education is continually diversifying to keep step with the profession. For instance, the area of professional and ethical aspects of electrical engineering is increasingly found in electrical engineering programs, either as a stand-alone course or as a topic discussed in conjunction with design (courses). Most view this as a positive development since it is often thought that the focus on professionalism and ethics is likely to help maintain the integrity and respect of the profession as a whole. In this paper we identify resource materials, background information, a syllabus, and outline for teaching a course on professional and ethical aspects of electrical engineering. Special attention is given to issues encountered when this topic is taught to a large class. In particular, it is explained how to turn the large class "problem" into an advantage that can actually enrich the educational process of teaching professional and ethical aspects of electrical engineering.**

***Index Terms*— Education, engineering ethics, large class, professionalism.**

I. Introduction

As electrical engineers become increasingly involved in a diversity of fields and interact with other professions, there becomes a need to reconsider the basic composition of the curriculum in order to ensure that electrical engineers are properly prepared for their careers. Although there clearly must exist a division between what we can expect someone to learn in college and what they must be expected to learn on the job, the place where the line should be drawn between the two is difficult to determine. Basically, the current electrical engineering curriculum is the result of a century-long debate over the composition and length of the program (topics and theoretical versus practical issues). Due to the fact that professors, industry, government laboratories, scientists, business people, and others have been involved in the ongoing process of electrical engineering curriculum enhancement, it is understandable that there is not always complete agreement on the composition of the curriculum. It is for this reason that it is difficult to convince everyone that any single topic should definitely be in the curriculum. Consequently, as engineering has diversified, the problem of what to put in or take out of the curriculum has become more acute.

On the other hand, there do seem to be certain areas of consensus on what is needed in the curriculum. For example, there have been initiatives to enhance the technical communication skills of engineers and to educate engineers on how to integrate what they have learned in a variety of courses, while taking into consideration practical issues, to then produce useful products (i.e., the emphasis on design). Such curriculum initiatives seem fundamentally important to establish engineers as the designers of new technological products and to enhance the way in which engineers conduct their professional communications. Another area that has been receiving more attention in academics is the area of ethics in engineering.[1] This topic naturally arises as one considers the broad spectrum of issues in design of products that are to be used by the public (especially if there are safety considerations). Moreover, it is fundamentally important to the development of professionalism in engineering (engineering as a profession is relatively young). Other professions, such as medicine and law, have required courses in ethics. Quite naturally, as the profession of engineering expands and diversifies, and as our products and services become more closely tied to other professions, as well as the public, it becomes increasingly important to study these topics early to establish certain standards. Currently, surveys show that engineers are quite well respected as professionals [1]; it is our responsibility to ensure that we maintain the highest standards of professional conduct. Hence, it seems logical to make our young engineers aware of the importance of ethics and professionalism in engineering.

In this paper we will examine some of the fundamental problems in introducing and teaching a course on professionalism and ethics in electrical engineering. We will, in particular, seek to answer some of the following questions. What resources are available for teaching such a course? What topics should be taught? What does an example syllabus look like? What, specifically, should the composition of the lectures be? If constraints are such that many sections cannot be offered then what is the best way to handle a large class size? If you are interested in a broader view of how engineering ethics is taught in the United States see [3].

In Section II we discuss the range of topics that can be treated in the course and describe a course in engineering ethics in the Department of Electrical Engineering at Ohio State University (OSU). Issues related to large class size, and

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[1] It is interesting to note that there also seems to be an increasing awareness of the importance of education on professional and ethical issues in industry (e.g., see the discussion in [2]).

how to turn it into an advantage, are discussed in Section III. Section IV contains a few concluding remarks.

II. A Course on Professional and Ethical Aspects of Electrical Engineering

In this section we outline the candidate topics that can be taught in a course on ethics and professionalism in engineering, provide a syllabus of a course at OSU, and provide a detailed description of each of the lectures. The course presented here should be viewed as an *example* of how to teach a course in this area. As indicated above, various constraints have dictated that a one credit course near the end of the curriculum is the best mode of instruction here at OSU. First, it was decided that a single course was best (as opposed to "ethics across the curriculum" [3]) to ensure that the proper set of topics was covered and due to constraints on the availability of instructors comfort able with teaching this topic. The course was placed at the end of the curriculum since by that time most of the students have already worked on an engineering job (a fact that we will later exploit).

It seems likely that the overall approach to teaching ethics and professionalism provided in this section will be useful for not only large engineering programs like OSU's but also for smaller programs where it is likely that there are fewer students. The approach here helps to focus the students' attention on the topic, does not significantly overload the curriculum, and still helps the students prepare for their design courses. We emphasize that if one had different constraints that led to other modes of teaching, then the course would certainly change. It is felt, however, that regardless, the reader can benefit from learning how such a course can be taught in the format that we do here at OSU.

A. Candidate Topics for the Course and Resources for Getting Started

There are many topics that can be discussed in the course; hence, one must be careful to not try to cover so much material that the treatment becomes superficial. The main topics to teach in the course are: 1) safety and risk with case studies; 2) engineering as social experimentation and its link with design with case studies; and 3) professionalism and organizational issues with case studies. Some very good resource materials are available in each of these areas. In particular, [4]–[8] should be consulted. It is recommended that the professor who is getting started in the area read [4] first, then at least two of the others [4]–[8], especially to show other perspectives on these topics and to gain exposure to wider variety of case studies. Other material, such as that in [9]–[13] can be supplemented as necessary. It is recommended that you avoid spending too much time on ethical theories at the expense of getting the students to debate case studies (engineering students tend to identify much more closely with case studies and become convinced of the importance of the material easier than via ethical theories). It is important to make some connections between technical design issues in engineering and safety, risk, ethical, and professional issues. Certainly, some time should be spent on codes of ethics (e.g., the IEEE's or ABET's), but a critical reading of one code in class and a discussion of the codes' limitations seems sufficient. If you happen to have many students majoring in one subfield of engineering, you may be able to focus more of your discussion on ethical issues that are particularly relevant to this area. For instance, for a focus on ethical issues associated with computers, a good resource is [6]. For more details on how these topics can be woven together into a course see the next section.

There are many other topics that could be taught in the course, especially if a three-credit hour required course can be devoted to the topic. For instance, it is desirable to try to include some discussion on history of engineering since engineering students typically do not see this topic elsewhere in the curriculum. Additional reasons for including the history of engineering are: 1) various events that shaped the history of engineering actually involved significant safety and ethical issues (e.g., the safety standards on the Titanic); 2) it seems important to present the history of the profession to show the student how we connect with the public and what benefits the profession has provided society (this helps to convince students that engineering is a profession in much the same way that medicine is a profession); and 3) you can show the students how the professional societies and their codes of ethics evolved. Overall, the importance of teaching history of engineering is similar to the importance of teaching history in general. The topics can help instill wisdom by providing a broader perspective, as well as help teach us to avoid past mistakes. For history of electrical engineering consult [14]–[16] and for a general treatment of engineering see [17].

Another topic one could spend some time on is philosophy of technology. My experience has shown that one can summarize the public's main philosophies of technology quite briefly to demonstrate how technology that is created by engineers is perceived by society. This seems most useful if you have severe time constraints (like we do at OSU). A good resource for this topic is [18]. While legal issues are certainly quite relevant it is often difficult to integrate these topics into the course due to time constraints. If you would like to introduce the basics, a good book to consult would be [19]. It is nice to treat topics in professionalism and organizational issues and one resource for this is [20]. There are many other books that can be used as assigned reading for book reports. For instance, see the references in any of the books listed above or [21] and [22].

B. The Course at Ohio State University

Ohio State uses the quarter system with each quarter ten weeks long; hence, for a one credit hour course there are ten lectures (each 48 min long). The course is graded pass/fail and is offered only once a year in the Autumn Quarter. Over the past seven years there have been an average of 120 students in the course. Thus, most people would consider this to be a large class size for the topic being taught. We have used [4] as the textbook for the course for the last seven years and this has worked reasonably well.

The general approach for the course is to lecture for the first half of the course and then have classroom discussions

for the last half where case studies in engineering ethics and professionalism are considered. There are four or five homework assignments that typically require the student to answer several questions from the text [4] and are used to expose the students to certain topics that we do not have time to cover in class such as other case studies in engineering ethics (e.g., the Challenger disaster). There are no exams since it is difficult to justify using class time for this and there is no final exam but there is a final project (where the students work on teams). Attendance is required; however, with a good excuse the students may miss one class.

The Department of Electrical Engineering provides a teaching assistant (TA) who grades the homeworks and attends each class and helps take attendance. We have developed a special way to take attendance for this size class. At the end of each class an "attendance question" (a type of mini-quiz) is asked. The students write their responses on a sheet of paper, write their name at the top, and turn their responses in to the TA on their way out of class. The results of these attendance questions are typically discussed in the next class period and actually play an important role in teaching the course to a large class as it is explained in Section IV.

We provide a syllabus of the class that is taught at Ohio State University and explain the contents of each of the lectures.

EE 481 Professional Aspects of Electrical Engineering Syllabus

Lecture	Topic/Assignments
1.	**Introduction and Overview** -Electrical Engineering as a Profession -The Impact of Electrical Engineering on Technology Today
2.	**Engineering Ethics and Decision Making** -Philosophy of Technology -Ethical decision-making strategy -Codes of Ethics
3.	**The Nature of Engineering** -Engineering as Social Experimentation -Relevance to Design -Responsibilities of Engineers, Case Studies (HW#1 assigned)
4.	**Engineer's Concern for Safety of the Public** -Assessment of Safety and Risk -Rights of Engineers, Whistleblowing (HW#1 due, HW#2 assign)
5.	**Case Studies in Education and Engineering Ethics : Your Experiences** -Ethical Dilemmas Encountered in the University (case studies) -Ethical Dilemmas Encountered on the Job(case studies) (HW#2 due, HW#3 assign)
6.	**Case Studies in Engineering Ethics : Your Experiences** -Ethical Dilemmas Encountered on the Job continued (case studies) -(HW#3 due, HW#4 assign)
7.	**Case Studies in Engineering Ethics** -Case Studies for Electrical Engineering -Discussion (HW#4 due) (Final project assigned)
8.	**Ethical Issues in Design** -Design Methodology and Ethical Issues Encountered -Case Studies and Discussion
9.	**Ethical Issues in Design : Case Studies** -Case Studies and Discussion
10.	**Engineers, Management, and Organizations** -Professional Responsibility and Employer Authority -Professional Issues on the Job (discussion) -Issues in career choice (Final project collected)

Lecture 1: Introduction and Overview:

In the first class we define a "profession" and explain why electrical engineering qualifies as a profession. We discuss the role of electrical engineering in society, its impact on the public, and the public's perception of integrity and professional behavior of engineers. We discuss the lack of role models for engineers and the treatment of engineers in the popular media. The state of the field of electrical engineering is overviewed and prospects for its future are discussed briefly. Next, we go over the syllabus shown above and then a reading list is handed out (one that includes the references at the end of this paper). The attendance question is: Name as many famous engineers as you can: 1) they do not have to be currently living; 2) they must be known by the general public; and 3) they can be fictitious. Students generally like this question and will spend extra time discussing it with each other to come up with good ideas (often they stay after class to do this). The intent of this question is to get the students to think about the famous engineers that have made significant contributions and to encourage them to aspire to greatness, even if this lies outside the field of engineering.

Lecture 2: Engineering Ethics and Decision-Making

Discussion begins with the results from the attendance question from lecture 1. To do this, the TA compiles a list of names from attendance question 1 and a transparency is displayed. Typical answers to the question include: 1) the "classics," Volta, Ampere, Ohm, etc.; 2) U.S Presidents (there is more than one); 3) TV/movie personalities (e.g., from Star Trek, Tucker); 4) owners/CEO's of large high-tech companies; 5) professors in our department; and 6) themselves (which always draws laughter).

The lecture begins with a discussion on the philosophy of technology and in particular the four philosophies of technology: technological anarchy, technophilia, technophobia,

appropriate technology. This helps to explain to the students how the public views the technology producing infrastructure and its products. This helps student understand the group of people that they will interact with as professionals. It is then explained how engineers provide many benefits for society but that sometimes there are disasters and ethical issues that arise due to safety requirements. We define engineering ethics and explain why engineers and other professions teach ethics. Then, we discuss the overall objective of the course: moral autonomy. We discuss issues in confronting moral dilemmas, trustworthiness, and how to integrate your personal life, moral integrity, and professional life. We introduce a strategy for ethical decision-making. Next, we read aloud and critique the IEEE Code of Ethics.

For the attendance question we ask them to name as many technologies and/or systems that: 1) electrical engineers are involved in designing and 2) involve important safety considerations. Electrical engineers often view their jobs as free of safety issues (e.g., if the student views themselves as an audio engineer). This question is designed to force the student to think about the serious safety issues that can arise in the products that electrical engineers design. Practically speaking, this question helps to sell the students on the importance of the class.

Lecture 3: The Experimental Nature of Engineering

First, we review the last lecture and provide a list of answers from the last attendance question. The students typically provide answers like: automotive systems (e.g., ABS), avionic systems, ground fault interrupter, power systems, etc.

The lecture starts with a definition and explanation of the concept of "engineering as social experimentation" from [4]. We explain the relationship between engineering and standard experiments, discuss the concept of informed consent, and discuss the role of engineers as responsible experimenters. We discuss accountability and law and its relationship to engineering. Case studies are woven throughout the lecture.

The attendance question asks: 1) For people who have worked on an engineering job: Can you briefly describe your involvement in engineering a product where "social experimentation" was used (focus on procedure); 2) If you cannot answer 1) what is your single biggest complaint/praise for the EE program at OSU (will pass results to the Department Chair). The second part of this attendance question is well received since students always have suggestions for the Department (often very good ones, and ones that we have addressed due to their suggestions). The first part is very effective due to the fact that two-thirds of the students in the class have already held an engineering job they have actually seen engineering as social experimentation at work.

Lecture 4: Engineer's Concern for Safety of the Public

We begin by overviewing the last lecture and discussing the results of the attendance question on engineering as social experimentation. The overall intent of this attendance question is to expose all the students to the issues that several of the students have already encountered on the job (in this way we essentially use the collective experience of a whole group of engineers). The students seem to really "have their eyes opened" since the experiences of their peers is often very close to what they read about in the text and what we discuss in class. To discuss the student responses to the question, the answers are scanned and the best ones are read aloud in class (keeping the student and company names anonymous and using the opportunity to discuss how each of these relate to engineering as social experimentation). Some of the student responses have included (paraphrased somewhat; however, I am borrowing the students exact words in many cases):

— "A turbidity meter was used to monitor if contaminants were getting into the water that goes into the river. When those meters failed to alarm us, and a white pigment went into the river, my project that focused on redesigning the monitoring station was given support."

— "On a recent co-op job my company had just shipped its latest and greatest computer product. After a few months in the field it was found to vastly lack the processor power it needed to do what it claimed to do. The fix that followed had to have the shortest turn around time I had ever seen. The fix was top quality, but the damage had been done. A full-scale test, or even simulation, would have predicted this problem before shipping."

— "My problem came with a company involved in the design and manufacturing of PC power supplies. Some manufacturing organizations, have focused on 100% minimal compliance and hence substituted parts to achieve their cost objectives. This resulted in unsafe final consumer products. An industry push for CSA and UL certification of power supply modules enhanced the minimal level achieved for standard subassemblies. Since the FCC and FTC act as police organizations it is not usually known that there is a problem until much mayhem occurs. When other companies began selling "smoking PC's" the industry began to push to use only modules which would meet UL and CSA standards. The minimalists were forced to up the ante or lose considerable business."

The students come up with many more like this and ones that focus on how input from consumers, either via complaints or surveys, are used in engineering redesign.

The main part of this lecture starts with a discussion on the engineer's concern for safety and how absolute safety is not attainable or affordable (specific examples are provided). We define risk, acceptability of risk, and assessment of safety and risk. Case studies are used and tradeoffs between safety and cost are discussed. Uncertainties in design and their effect on risk are discussed (i.e., capability versus duty) with specific case studies. We discuss fail-safe systems, how to test for safety, and cost-benefit analysis with safety as a consideration. We discuss the rights of engineers and the basic right of professional conscience. Next, we discuss whistle-blowing, its definition, moral guidelines, and procedures.

To give the students a taste of whistle-blowing we use the attendance question to ask: 1) For those of you who have had a job in industry—engineering or nonengineering (two-thirds have had one in engineering): Have you encountered a moral dilemma? Have you witnessed unethical practices? Please

provide a brief description. 2) Others: Have you encountered a moral dilemma at OSU that is related to engineering? Please provide a brief description. Please do not use people's names or the names of companies. I will accept more detailed explanations and I reserve the right to discuss these in class.

Lectures 5–6: Case Studies in Engineering Ethics

This entire lecture focuses on the results of the attendance question from the last class on whistle-blowing. Just like the attendance question on engineering as social experimentation, the high number of responses to the whistle-blowing question provides a wide range of very interesting responses. The students are often quite shocked to hear what their peers have already experienced on their engineering jobs.

Normally, we start with the responses to the OSU part of the question where the students identify moral dilemmas that they have encountered in school. While at first glance one may think it useless to discuss these issues, it turns out that you can make clear connections to similar ethical issues that arise on the job so that the students can be made to think carefully about professional engineering ethical issues also (indeed those in academics also qualify under this heading). Typical responses from the students include:

— Cheating on exams/homeworks: We discuss the importance of giving credit where credit is due and how one can cheat themselves of their own education.

— Use of a "file" of past students results for labs and tests: We discuss how this can adversely affect the learning process and how there is a different intent than in engineering where it is often the case that you try to use all available information.

After the student's responses have been discussed and these have been related to the workplace I take my turn of reporting "unprofessional behavior" that I have witnessed in this class and elsewhere in the program. To do this I keep it humorous by beginning with a "Calvin and Hobbes" comic where Calvin decided, after long soul-searching, that he should not cheat on his ethics test. Then I ask them if coming late to class, doing homework for other classes, signing other peoples names on attendance questions, or copying other peoples ethics homeworks is unethical or at least unprofessional. This really gets their attention since by this point in the class they have figured out the system and several have already started to challenge it (e.g., they notice that we take attendance at the end of class so some students start showing up late for class). Students will actually agree with me and point out how if you are on the job and start coming late for meetings that this is very unprofessional and will adversely affect your career.

Usually, well before Lecture 5 is over we start on the engineering-related whistle-blowing answers that the students provided. Now, while not all of the responses are very good, and some really cannot be read in class due to their serious nature (where one could easily figure out what company was being discussed) after a scan of their responses several very good ones can be found. As with the engineering as social experimentation attendance question, the students seem quite intrigued with the other student's responses and find that they really highlight the points about engineering ethics in the text and lecture. Some responses that students have provided include (paraphrased somewhat; however, I am using the students exact words in many cases):

— "I was employed for one day at Company X, a place where fuels and other chemicals are tested and created. I was hired as a utility person cleaning glassware, etc. When faced with disposal of heavy metals I inquired as to their procedure. They told me to dump it down the drain and don't ask questions. Clearly this was wrong, but I agreed to do it. Again, when two quarts of diesel fuel was to be disposed, I asked and got the same response. The next day I was fired for being an "environmentalist." I contacted a relative who has ties with the EPA. Recently, I saw that Company X was fined by the EPA for infractions." (We encounter an alarming number of students that complain that they are required to dump hazardous waste or students who dump things down the drain that they are not sure about the laws on these chemicals.)

— "When I co-oped at Company Y my supervisor asked me to do significant corrections on a programmable logic controller (PLC) program that controls the robots on a conveyor. At that time I did not have a lot of experience with PLC's. I made some changes, but was not sure whether I did things correctly. So I asked the supervisor to check it for me, but he did not have time. So he said "it is fine, I trust you." Later on they found that I had disabled the main safety subroutine. Nothing happened but it was possible that people would have been injured from the mistake and some very expensive equipment (worth millions) could have been damaged." (We find many others like this on competence and the students are then reminded of relevant statements from the IEEE Code of Ethics on this topic.)

— "I used to work for a civil engineer modeling a sewer system. We collected observations from survey crews. One day a photo came in of a company actively dumping industrial waste chemicals (paint) into a sewer. A note was attached, reporting that this is illegal. No one did anything about it. (We discuss diffusion of responsibilities in organizations and responsibilities of the co-op student in this situation.)

— "While on a co-op job I was involved with the production of a product that did not function properly. This product was not capable of performing some of the advertised functions. The product was released to the public because it was considered by the company to be more cost effective to release the faulty product than it was to hold up production" (We discuss the ethics of specifications of products.)

There are many more responses similar to these. A student working for military nuclear facility has reported observing practices of noncompliance to operating rules. Others have reported the use of damaged or clearly low-quality parts in production due to pressing production schedules, practices of illegally copying software, extraordinary gifts from suppliers, people not working hard on the job, people cheating on expense sheets and time cards (one student got their boss fired by reporting that he had done this), and billing expenses improperly. One student indicated that "I have a few moral dilemmas but due to confidentiality agreements I cannot discuss them" and usually one or two students will say that they have encountered no problems.

The attendance questions for Lectures 6–10 are usually kept flexible and a question will be asked about students views on one of the more controversial issues discussed (sometimes this is made into a survey-type question so that their responses can easily be tabulated and discussed in the next class).

Lecture 7: Case Studies in Engineering Ethics

After discussing the attendance question from the last lecture we discuss a variety of cases in engineering ethics that are particularly relevant to electrical engineers. To do this, we have searched the literature for such cases, and in addition to the BART case [4], we have found the following to be particularly useful:

1) Computers and police cars (from [5]): The story of the computer programmer who raised concerns about the over-loading of the computer that handled 911 calls. Good for discussion of confronting a professional concern, issues in organizations, touch on whistle-blowing.
2) Honesty in specifications and bidding (from [4]): Team bids for a NASA project that they feel they will never be able to meet the specification for. Good for honesty in specification and bidding and issues of customer interface.
3) Whose property? (from [6]): Story about a computer programmer who uses a modified version of a program he had developed with a company he used to work for at his present job. Nice to show how problems can grow, issues of ownership of computer programs, issues in organizations.
4) Automotive components (from [6]): Nice for a discussion on design challenges, time deadlines, safety, testing, and legal issues.

Notice that these cases are not so narrow as to give the impression that electrical engineers do not get involved in ethics as it relates to other areas of engineering that electrical engineers will often get involved in. However, it has been found that using cases that are clearly connected to electrical engineering helps to hold the student's interest and convince them of the relevance of the class topics to their own careers.

Lectures 8–9: Ethical Issues in Design: Case Studies

After discussing the attendance question from the previous class, we discuss design methodology and how ethical issues enter design in electrical engineering. Next, clear examples of how ethics enters the technical design process are given in a variety of areas of electrical engineering:

1) Solid State Sensors/Computers/Control: Air–Fuel Ratio (A/F) Control: Here, we discuss the design of a A/F ratio control system. The technical problem is presented and a complete solution is provided. Then, it is shown that if you are really smart in the design (discuss competency issues) you can achieve even higher performance operation (that is tied to reductions of pollution). We discuss sensor reliability and explain how to incorporate "robustness" to certain types of sensor failures or sensor performance degradation into the design.
2) Computer Design: General ethical issues encountered include intellectual property, pirated software, computer security and privacy, computer reliability (discuss the A/F ratio control problem as an example where reliability is important).
3) Computers/Controls/Motors: Discuss brake system control and show specific designs and how better braking performance can lead to safer designs (e.g., in ABS get better vehicle stability ("steerability") and shorter stopping distances.
4) Communications/Signal Processing: Discuss the design of an arming/firing mechanism for a missile, issues in safety of operation of a complex device, reliability of the mechanism, plus a few issues in weapons development. Also, discuss the design of a device for measuring how far you walk; here, we design difficulties, honesty in specifications and its relation to marketing and sales.
5) Electromagnetics and Automated Highway Systems: Here, give a brief introduction to automated highway systems and a broad summary of the ethical and safety issues involved in the design and implementation of such a complex system.
6) The hype of new technology: Discuss the sometimes unprofessional behavior associated with the hype that surrounds certain new technologies and the importance of keeping a level head and evaluating advantages and disadvantages of all competing technologies.

The importance of these two lectures cannot be overstated. The above examples help connect in the student's mind basic technical engineering design issues and technical issues from all their other engineering courses to broad issues in ethics and professionalism.

Lecture 10: Engineers, Management, and Organizations

After overviewing the last two lectures and going over the responses to the attendance question, professional responsibility and employer authority are discussed. To do this we often review, together in class, the pamphlet [23] provided by IEEE. We relate this back to earlier discussions in class and the students get involved in the discussions.

Next, we discuss professional issues in the workplace. To do this we sometimes discuss examples that the students came up with and other times we will discuss whether or not engineers should unionize. Other times we will discuss women's issues in engineering (this has arisen from requests of some women students). For example, one student had written in on an earlier attendance question (from lecture 4):

— " When I worked at company XYZ, a supervisor and I were discussing some of my colleagues. We had just begun to discuss the only two female engineers who worked at XYZ, and I asked why one of them had not been promoted. This person had been doing good work for the company for years, and still was working on CAD, a job usually reserved for technicians and/or new engineers. His reply was (paraphrasing) " It is just as well, women are much better at tedious tasks than men." I don't know if this supervisor was in a position to block my co-worker's advancement,

but clearly he had a lot of unwelcome stereotypes to overcome."

Several others on women's issues are used and these often make for very lively discussions. Other times we discuss issues in organizational issues as they relate to ethics and professionalism. For instance, one student wrote in response to Lecture 4's attendance question:

— "While working at my internship I heard of jobs coming into the shop that contained asbestos-based insulation. The sales engineer that took the job had difficulty relaying that information to the people in the shop that were to "strip" the units. Because of this lack of communication, the people who stripped the units did not wear the proper safety equipment and were exposed to the asbestos. This may not have occurred if more emphasis was put on communication between sales engineers and shop foremen." (For this we discuss how it is important to have the organization structured properly so that professionalism and ethical behavior are facilitated.)

One topic that we have discussed several years is the issue of discrimination and preferential treatment in hiring. First, a lecture is given on the topic from [4]. Then the views of the students are solicited on the issue. Both years that we discussed this topic the students successfully identified all the pros and cons to preferential treatment and the classroom discussion could be characterized as lively but productive. Overall, this topic is used to show them how to be tolerant of other views and to show them how to carry on a discussion on a sensitive issue in a professional manner. In fact, after the discussion is done the students are informed of the real motive in discussing this topic.

The Final Project: There is a final project where students work in teams of up to four persons to solve a complicated problem in engineering ethics. Some problems that have been given include:

1) Ground fault interupter design problem (modified from one given in [24]): In this problem the students are presented with a scenario where a product that they are involved with has killed someone and they must decide how to re-design the product.
2) Automated highway systems: The students are told that they are in a large consortium that is charged with developing an automated highway system for the United States. They are asked to highlight all the ethical problems that could be encountered in the development of such a system and they are asked to specify how ethical problems should be brought to the attention of administration, including complete instructions for a whistle-blowing procedure.

Other final projects could focus on computer ethics, brake system design, or writing a code of ethics for a company.

III. Teaching Professional Aspects of Engineering to a Large Class

In this section we outline the primary issues encountered in teaching ethics and professionalism to a large class. Please keep in mind that the ideas here arise in response to the given situation of having a large class size. The author understands that there are several clear advantages to having a small class size for this or any other topic including: 1) ability to maintain rapport; 2) ability to "connect" with the class; and 3) ability to give each student more attention to draw them into discussions and make sure that they are performing well in the class. Here, we take the view that it is better to seek the best ways to cope with the large class size problem than to ignore the issue and allow it to degrade the quality of instruction.

A. Turning Large Class Size into an Advantage

The trick to providing a valuable learning experience for a large class in this topic is to view class size as an advantage rather than a disadvantage (this view has emerged from seven years of teaching this course and having to cope with all the constraints listed above). There are several ways to turn the large class size into an advantage and each of these is treated below.

Discussion of Ethical Problems Encountered by Students in Engineering Industry: See Table I where we summarize the value of some of the attendance questions for a large class.

From Table I one can see that the safety (Lecture 2), engineering as social experimentation (Lecture 3), and whistle-blowing (Lecture 4) attendance questions are the most useful questions in terms of gaining an advantage from having a large class size. Actually, the reader should be made aware that some students are not willing to write down their responses to some of these questions; they often come discuss them with me in private and then often they will allow me to use a paraphrased version of our discussion in class. This is how our focus on women's issues in Lecture 10 has arisen.

Ethics and Professionalism at the University: In addition to bringing the students' experiences from industry into class from the attendance question for Lectures 3–6 we bring up the whole topic of ethics and professionalism at the university. This tends to provide the students with a discussion of ethical issues that is particularly close to home. For instance, the students become more aware of the unethical behavior that is really going on (e.g., some are surprised at how much cheating on homeworks or tests is identified or that lab equipment is stolen). Also, it provides the lecturer with the opportunity to discuss the professional behavior of the students in the class. In particular, with a large class size one clearly must have a large room so that by fire laws you must have many exits. Now, when the students learn that the attendance question is at the end of class they soon learn that they can be late and I have a hard time "catching them." Hence, as the quarter wears on there are several students who will significantly abuse the attendance policy by coming to class very late. Now, by the fourth class I will typically "nail" a student who comes in about 15 min late and ask them in front of the class what the problem is (and most often there is no good excuse). By the time we come to discuss ethical and professional issues at OSU I have the opportunity to raise the issues of unprofessional behavior (that include coming late to class, doing homework in class, turning in someone else's name for the attendance question, copying homeworks, etc.). Somehow the students feel that

TABLE I
USING ATTENDANCE QUESTIONS FOR LARGE CLASSES

Attendance Question	Value of Question for Large Class
Lecture 1: Name as many famous engineers as you can: (i) they do not have to be currently living, (ii) they must be known by the general public, and (iii) can be fictitious.	With a large number of students many very good answers are provided so that the students really become convinced that there are many famous engineers (good for role models).
Lecture 2: Name as many technologies and/or systems that: (i) electrical engineers are involved in designing and (ii) involve important safety considerations.	With a large class, a large number of very innovative answers are provided so that the students quickly become convinced that safety is an important issue for electrical engineers.
Lecture 3: (1) For people who have worked on an engineering job: Can you briefly describe your involvement in engineering a product where "social experimentation" was used (focus on procedure); (2) If you can't answer (1) what is your single biggest complaint/praise for the EE program at OSU (will pass results to the Department Chair).	With a large class there are always several good responses to this question that can be directly tied into the discussion on engineering as social experimentation. As the results of this question are discussed the students see a clear connection between their classmates and engineering as social experimentation. The part about the EE program at OSU provides a method to get complaints to the administration. Traditionally, these have in some cases actually involved ethical issues.
Lecture 4: (1) For those of you who have had a job in industry - engineering or non-engineering (two-thirds have had one in engineering): Have you encountered a moral dilemma? Have you witnessed unethical practices? Please provide a brief description. (2) Others: Have you encountered a moral dilemma at OSU that is related to engineering? Please provide a brief description. Please do not use people's names or the names of companies.	With a large class there are always many good responses to this question that provide the class with lively discussion. The students always seem amazed that their fellow classmates have encountered such problems and they really seem to connect with ethical issues when they know that their fellow classmates have already encountered them. The methods of the class can be used to get the students to carefully analyze the moral dilemmas identified by the students and formulate their own opinions. Consensus is often not reached since with a large number of student a broad representation of views is always present.

the university environment is "artificial" as compared to the "real world." However, I make connections between their behavior in class and what they might do in industry (e.g., analogies between coming late to class and meetings at work are made, misrepresenting people's contributions to a group project, covering for someone who is habitually late or a poor performer). This helps them to examine their own behavior and to make a clear connection to unprofessional behavior in industry.

It is emphasized that in a small classroom that only has one door and a small number of students such behavior is not nearly as likely to occur. Hence, for normal class sizes there is not normally the opportunity to conduct such a discussion on professional issues (at least not as effectively).

Discussions on Case Studies: At first glance the reader may think that it would be very difficult to conduct discussions on case studies in engineering ethics, which is a very critical part of the class. Clearly, there may be some advantages to a small class size to draw more students into the discussions; however with a large class size the discussions can be made quite effective if they are led properly. Basically, the discussions with a large class size tend to be quite lively if the leader of the discussion can properly encourage the students to get involved and ask the class the right questions to keep the discussion focused. When you have a large class size you will always have several students who are not at all afraid to speak up and express their own views and this tends to sustain the discussions. Also, with a large class there are always students that feel strongly about both sides of an issue and this can tend to keep the discussion lively. Overall, I have found that some very good discussions can be conducted and we can get to the core difficulties in case studies very quickly.

B. Additional Issues Due to Large Class Size

There are a few more issues that arise due to the large class size that are worth mentioning. First, when you have so many students it becomes more likely that there will be some students who bring their ethical dilemmas into your office, or perhaps seek to discuss them with you in the halls. In these situations I try to get them to find their own answers by asking them to consider various concepts that we discussed in class. Of course, as is always the case with large classes, you can expect a significant number of interruptions in your office. There are additional problems with students arriving late for class as discussed above. Another problem is that since we only offer the course in the autumn quarter and it is required for graduation it is difficult for some students to fit it into their schedules (especially with conflicts due to co-op jobs). To accommodate these students I have adopted a policy where an independent studies class in ethics and professionalism is offered so that students may finish their degrees on time. This independent studies class consists of reading the text [4] and answering a significant number of the "study questions" that

are at the end of each section of [4]. The student writes a report on these and turns them in by the end of the quarter.

IV. Concluding Remarks

We have provided the motivation for offering a course in electrical engineering ethics and professionalism and presented a syllabus for a course that has been taught for the past seven years at Ohio State University (of course it was not initially offered in this form; it evolved into this form). We provided a detailed description of what was taught in each lecture and highlighted a novel approach to teaching the course to a large class. The main key to turning the large class size into an advantage is to request, then use cases in engineering as social experimentation and engineering ethics as the focus of discussions in class. The students find this discussion very relevant to their careers and it makes the topics of professionalism and ethics seem very important for the careers they are about to start.

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