Designing a sustainable and dynamic problem-solving class for first-year engineering students

Edward A. Jackson and Mani Mina
Department of Electrical and Computer Engineering, Iowa State University

Abstract

As the fields of engineering expand and introductory courses become more compressed, it has become a greater challenge to structure first-year classes to prepare students adequately both for the remainder of their formal education and for the workplace. We review the objectives of first-year classes and some of the traditional methods used in teaching them. We also introduce our attempts in the last few years at developing a sustainable and dynamic first-year electrical engineering class at Iowa State University. Discussion of classroom, laboratory, and out-of-class learning is included, along with some of our results.

Introduction

The increasingly rapid growth of the various fields of engineering has led to great challenges in education, and many proposals have been made regarding changes in curriculum[1-3]. The needs of first-year university students have especially changed; quickly changing and evolving technology demands more than ever that students continue to learn efficiently throughout their professional career. To this end, a first year course must provide the student with a number of objectives:

- Identify the scope of the particular field which he or she has chosen to study;
- Begin to learn the process of problem solving, recognizing that each problem is unique and that a single, rigid solution process cannot be universally applied;
- Identify personal methods of learning and how to objectively assess one's own understanding of a problem or subject;
- Dispel the myth that spending more time on a problem will automatically produce better results, and instead learn to spend time more productively; and
- Learn some basic principles needed in engineering, identifying what is fundamental and what is derived. There are very few basics.

The subject matter we cover in our first-year class at Iowa State University does not differ greatly from that taught at many other institutions; it includes some mathematical basics (review of trigonometry, very basic vector and matrix operations, brief introduction to complex numbers) as well as laboratory work in programming and computer-assisted mathematics. An emphasis on the learning process and the formation of student communities, however, makes the class unique.

Traditional Approaches

First-year engineering courses are usually constructed as problem-solving classes. The subject matter covered is intended to complement other introductory classes in preparing the student for higher-level courses, and may include mathematical background, computer programming exercises, and introduction to computer-aided design and analysis tools as well as design-related problems[3-4].

Because the class is strongly oriented toward problem-solving, students may be given a "flow-chart" method of solving problems, accompanied by a large number of examples. The problems are usually simple, based in math and physics, with the emphasis on the method. This approach does make students adept at solving a particular class of problems, but on its own, it also develops the habit of "formula plugging" that is distasteful to many instructors.

In many cases, what was once a full-year introductory course has been reduced to a single semester. This reduction, along with more condensed introductory courses (in the case of electrical engineering) in areas such as circuit theory and electromagnetism, has taken place in order to make room for an increasing number of advanced elective courses. The proliferation of these higher-level courses reflects the ever-expanding field of engineering[4-5].

One result of this shortened introduction is that many courses now cover only computer programming (C, C++, Fortran, etc.) and perhaps a short introduction to a design tool relevant to the particular field. The attempt is then made to teach the other subjects mentioned above in a computer programming context.

Iowa State's EE185 Class

For the past few years, freshmen in electrical engineering at Iowa State University have enrolled in EE185. This is our first-year course in which we attempt to achieve the traditional educational goals while also encouraging an understanding of the learning process and the formation of communities within the student population.

In EE185, we encourage our students to analyze their own learning methods and to take on challenging problems early in their university career. An important benefit of this experience is that most students quickly gain a greater understanding of themselves and of what the experience of studying and practicing electrical engineering is like on a daily basis. We believe this has changed the nature of the students' relationship with the major department and affected their choices about their academic career. Students are encouraged to discuss their ideas, think, and communicate their thoughts. They are asked key questions such as "Why did you choose this field?" "What do you think engineering is about?" and "What is so special about you?"

The purpose of the first few assignments is to encourage introspection; that is, to get the students to observe critically their ways of approaching the problems, the challenges they face, and the solutions they find. The encouragement for communication at the early stage, which is reinforced in their orientation class, has made some students realize they do not want to be in engineering and leave the department and the college within the first few months of the term. On the other hand this will reinforce some students' will to stay in the department and face the challenges.

The semester begins with word problems, letting students get started with problem-solving in a non-technical way and encouraging them to think creatively. An example of such a problem is this: A group of animals at the zoo has 100 feet and 30 heads. How many animals are there? Students are given a few minutes to discuss the problem, and the first answer is usually that there must be 20 four-legged animals and 10 two-legged animals. This answer, of course, is the result of solving two equations in two unknowns, but tacitly assumes that all animals have either two or four legs. Other students, however, will suggest that there might be 25 four-legged animals and five snakes, or 30 snakes and 100 clams, or some other unexpected solution.

The semester continues with a variety of subjects which are typical of first-year courses, including basic ideas in probability, review of trigonometry, and introductions to matrices, vectors, and complex numbers. Throughout the course, students are encouraged to use the same kind of creative thinking used in the word problems.

At the same time, students are in a once-a-week laboratory where they learn the basics of C programming and computer-assisted mathematics. Each laboratory session also includes a brief demonstration designed to illustrate qualitatively some physical principles important in electrical engineering. An effort is made to identify those students with more advanced programming skills and give them appropriately challenging projects; however, the emphasis is on communication, with the laboratory grade based on student reporting.

An optional second semester (EE186) is also offered. It is a single credit hour class that comprises only a laboratory section, and gives the students a great deal of latitude in choosing projects according to their own interests. The grade is again based on communication and reporting, but the students also benefit from the self-guided exploration. Although the experience is academically important, many students describe EE186 as a class they take “for fun.”

One of the most important aspects of EE185 is the use of more advanced undergraduate students as mentors. The mentors play an especially important role in the laboratory, where they can work one-on-one with students to help them through difficulties as they arise.

Although the mentors are under the supervision of faculty and graduate teaching assistants, they have some advantages in working with the students. Because the mentors are also undergraduates (many only a year or two removed from EE185 themselves), they and the students are in a similar academic and social context. Because of this, the mentors can often develop closer working relationships with the students than is possible even for a graduate TA. The advantages to the student continue long past the end of the semester, as these relationships help to encourage an active academic community within the department.

Another important role the mentors play is to increase the diversity of ways of thinking to which the students are exposed. Over the course of a semester, the student will likely work with the instructor, a graduate TA, and two or three undergraduate mentors. The different responses the student will inevitably receive to similar questions help to teach the notion that problems do not necessarily have a single unique or best solution, and that creativity is as important as technical mastery.

In conjunction with the EE185 class, our department has also created a more formalized learning community for first-year students. Participants are enrolled in the same courses in math,

chemistry, and physics. Undergraduate mentors provide assistance in all of these subjects at regularly scheduled study groups. This provides another means of developing a thriving academic community in which students work with one another in solving their academic difficulties. The hope is that this will develop into a habit that they will carry into the workplace.

Summary of results

In some cases, we were alarmed since we saw an increase in the number of first-year students leaving the department to change majors. However, we believe (and in many cases have interview evidence) that these students would have eventually left the department anyway, either by choice or because of poor grades. Indeed, many in the latter group might have otherwise left the university altogether. The overall graduation rate of the department remains stable.

Many of our former students have gone on to play very active roles in campus laboratories, research groups, and academic societies. It is also encouraging that a large number of them are interested in becoming involved with future EE185 classes by becoming mentors themselves. This may be the best possible affirmation that the students feel they gain great benefits from the mentorship program.

At the end of each semester, students in every Iowa State course fill out anonymous course evaluations. Our students in EE185 typically rate the course at 4.3 out of 5.0 when asked about overall satisfaction. Over 90% of the comments students provide indicate that they believe EE185 will have a lasting effect in their academic and professional lives.

Many of the developments in EE185 have been the result of student feedback, and we continue to use that as an important means of assessing our success.

Conclusion

We have constructed a first-year electrical engineering course which covers material similar to that of most traditional courses, but is augmented by an emphasis on understanding one's own learning methods. Students are encouraged to approach problem solving with an open mind, rather than trying to apply a rigid process. The class experience is enhanced by the presence of undergraduate mentors who provide guidance and intellectual diversity that would otherwise be lacking. The overall result is that students develop independent learning skills which will allow them to continue to adapt to changing technology throughout their careers.

That students report high rates of satisfaction and a desire to become involved in the course as mentors is a strong indication that they perceive it as a valuable experience.

1. E. Seymour, “Tracking the Processes of Change in US Undergraduate Education in Science, Mathematics, Engineering, and Technology”, Issues and Trends, Stephen Norris editor, John Wiley & Sons, Inc. pp 79-105, 2001

2. S. T. Fleischmann “Needed: A few good knights for the information age-competence, courage, and compassion in the engineering curriculum,” *IEEE Frontiers in Education Conference*, 2001. 31st Annual , Vol. 3 , S1B-8-13, 2001.

3. C. da Rocha Brito, M. M. Ciampi, R. C. Molina “Engineering program under the new paradigm of education,” *IEEE Frontiers in Education Conference*, 2001. 31st Annual, Vol. 3 , F4B-7-14, 2001.

4. C. Fried “Are required courses meeting industry demands?” *IEEE Potentials* , Vol. 20, Iss. 3 , pp 39-40 Aug.-Sept. 2001

5. M. Mina and N. Anderson “A new framework for teaching Electromagnetism: How to teach electromagnetism to all levels from Freshman to advanced level students,” submitted to 2003 ASEE annual conference, Jun 23-25, Nashville, Tennessee.

EDWARD A. JACKSON received his B.S. in physics from Iowa State University in 2002 and is now a candidate for an M.S. in electrical engineering. He has been a teaching assistant for first-year electrical engineering classes, and in 2004 received a graduate Teaching Excellence Award. His research has focused on signal measurement and fingerprinting methods for use in computer network security applications.

MANI MINA is an adjunct assistant professor in electrical and computer engineering and the director of Spacecraft Systems and Operation Laboratory (SSOL) at Iowa State University. He has been a recipient of several teaching and research awards. His research interests include physical layer measurements and testing, optical networking, nondestructive testing and evaluation, and innovative methods of teaching technology.