CHAPTER 1

INTRODUCTION: TEACHING ENGINEERING

It is possible to learn how to teach well. That is the thesis of this book. We want to help new professors get started toward effective, efficient teaching so that they can avoid the "new professor horror show" in the first class they teach. And by exposing them to a variety of theories and methods, we want to open the door for their growth as educators. Since one goal is immediate and the second is long-term, we have included both immediate how-to procedures and more theoretical or philosophical sections. Written mainly for Ph.D. students and professors in all areas of engineering, the book may be used as a text for a graduate-level class or by professionals who wish to read it on their own. Although our focus is engineering, much of this book should be useful to teachers in other technical disciplines. Teaching is a complex human activity, so it's impossible to develop a formula which guarantees that it will be excellent. But by becoming more efficient, professors can learn to do a good job and end up with more time to do other things such as research.

1.1. WHY TEACH TEACHING NOW?

The majority of engineering professors have never had a formal course in education, and some can even produce a variety of challenging rationalizations why such a course is unnecessary:

1 I didn't need a teaching course.
2 I learned how to teach by watching my teachers.
3 Good teachers are born and not made.
4 Teaching is unimportant.

5 Teaching courses have not improved the teaching in high schools and grade schools.
6 Engineers need more technical courses.
7 If I am a good researcher, I will automatically be a good teacher.
8 Even if a teaching course might be a good idea, none is available.

1 The first criticism can be answered in several ways. Just because someone did not need a teaching course does not logically imply that he or she would not have benefited from one. What is more important, times have changed. In the past, young assistant professors received a good deal of on-the-job training in how to teach. New assistant professors were mentored in teaching and were expected to teach several classes a semester. Now, mentoring is in research, and an assistant professor in engineering at a research university may teach only one course a semester. In the past the major topic of discussion with older professors was teaching; now it is research and grantsmanship. Because of these changes, formal training in teaching methods is now much more important. Van Ness (1989) has presented a detailed description of the changes in chemical engineering education which closely match changes in other areas of engineering education.

The problems facing engineering education have also changed. According to demographic studies, the number of traditional engineering students—white, male eighteen-year olds—is expected to go through a minimum from 1992 to 1994 and then increase very slowly (Hodgkinson, 1985; Reynolds and Oaxaca, 1988). In order to have enough engineers to remain internationally competitive, we must recruit, teach, and retain nontraditional students such as women and underrepresented minorities. There is also a moral imperative for reaching out to these nontraditional students. They offer different challenges and require different educational methods. A related problem is how to encourage enough U.S. citizens, particularly women and minorities, to earn a Ph.D. and then become educators. Many students see the workloads of assistant professors as oppressive and do not want the sword of the tenure decision hanging over their heads. A course on efficient, effective teaching would reduce the trauma of starting an academic career and help these students to see the joys of teaching.

2 You undoubtedly learned something about teaching from your teachers, but what if they were bad teachers? Even if you did have good teachers, this method at best gives the new professor a limited repertoire and does not provide for any of the necessary practice. This approach also does not help you incorporate new educational technology into the classroom unless you have had the rare opportunity to take a course from one of the pioneers in these areas. An opinion contrary to this is given by Highet (1976, p. 112), who argues that a course on education during graduate study is not needed since students can learn by watching good and bad teachers.

3 Some of the characteristics of good teachers may well be inborn and not made, but the same can be said for engineers. We expect engineers to undergo rigorous training to become proficient. It is logical to require similar rigorous training in the teaching methods of engineering professors. Experience in teaching engineering students how to teach shows that everyone can improve her or his teaching (e.g., see Wankat and Oreovicz, 1984; Stice, 1991). Even those born with an innate affinity for teaching or research can improve by study and

practice. Finally, in its extreme, this argument removes all responsibility and all possibility for change from an individual.

4 There is no doubt that teaching is very important to students, parents, alumni, accreditation boards, and state legislatures. Unfortunately, at many universities research is more important than teaching in the promotion process. When assistant professors are denied tenure, it is because of lack of research, not because they have not been good teachers. An efficient teacher can do a good job teaching in the same amount of time an inefficient teacher spends doing a poor job. New professors who study educational methods will likely be better prepared to teach and will be more efficient during their first years in academia.

5 There is a general trend toward reducing the number of courses in pedagogy and increasing the number of content courses for both grade school and high school teachers. However, there is no trend toward zero courses or no practice in how to teach. The optimum number of courses in teaching methods undoubtedly lies between the large number required of elementary school teachers and the zero number taken by most engineering professors.

6 The demand for more and more technical courses is frequently heard at both the undergraduate and graduate levels. At the graduate level some of the most prestigious universities require the fewest number of courses. Thus, arguments that instructors must cover more technical content lack conviction at the graduate level. Courses on teaching can be very challenging and can open up entirely new vistas to the student. A course on teaching methods will be useful to all students even if they go into industry or government since logical organization and presentation of material are important in all areas.

7 Unfortunately, most research shows that there is almost no correlation between effective teaching and effective research (see Section 17.3 for a detailed discussion). Frequently heard comments to the contrary often appear to be based on examples of good researchers who are also good teachers, while ignoring examples of good teachers who do not do research and examples of good researchers who are poor teachers. This should not be interpreted as a statement that engineering professors should not do research. Ideally, they should strive to do both teaching and research well, and they should be trained for both functions.

8 There are a few courses in teaching in engineering colleges (e.g., Wankat and Oreovicz, 1984; Stice, 1991), and at the University of Texas at Austin the teaching course has been offered since 1972 (Stice, 1991). Many, if not most, universities offer teaching workshops either before the semester starts (e.g., Felder et al., 1989) or during the semester (e.g., Wentzel, 1987). Professional societies such as the American Society for Engineering Education (ASEE) also frequently offer effective teaching programs.

There are additional good reasons for learning how to teach. Teaching when you don't know how may be considered unethical! Canon 2 of the Accreditation Board for Engineering and Technology (ABET) states, "Engineers shall perform services only in the areas of their competence" (see Table 12-1). Since teaching is a service, teaching when one is not competent is probably unethical. Also, the ASEE Quality of Engineering Education Project concluded, "All persons preparing to teach engineering (the pretenure years) should be required to include in their preparation studies related to the practice of teaching" (ASEE, 1985, p. 156).

1.2. THE COMPONENTS OF GOOD TEACHING

Exactly what characterizes a good teacher? Many adjectives come to mind when this question is asked: stimulating, clear, well-organized, warm, approachable, prepared, helpful, enthusiastic, fair, and so forth. Lowman (1985) synthesized the research on classroom dynamics, student learning, and teaching to develop a "two-dimensional model" of good teaching. The most important dimension is intellectual excitement which represents the teacher's "obligation to knowledge and society" (Elbow, 1986, p. 142). This dimension includes content and performance. Since most engineering professors think content is the most important, making this dimension the most important agrees with common wisdom in the profession. Included in intellectual excitement are organization and clarity of presentation of up-to-date material. Since a dull performance can decrease the excitement of the most interesting material, this dimension includes performance characteristics. Is the professor energetic and enthusiastic? Does the professor clearly show a love for the material? Does the professor use clear language and clear pronunciation? Does the professor engage the students so that they are immersed in the material?

The second dimension identified by Lowman is interpersonal rapport which is the teacher's "obligation to students" (Elbow, 1986, p. 142). Professors develop rapport with students by showing an interest in them as individuals. In addition to knowing every student's name, does the professor know something about each one? Does he or she encourage them and allow for independent thought even though they may disagree with the professor? Is the professor available for questions both in and out of class? Although engineering professors do not uniformly agree that interpersonal rapport is important, students consistently include this dimension in their ratings of teachers (see Section 16.3.2). Note that at times the content and rapport sides of teaching conflict with each other (Elbow, 1986).

How do these two dimensions interact? The complete model is shown in Table 1-1. Lowman (1985) divides intellectual development into high (extremely clear and exciting), medium (clear and interesting), and low (vague and dull). He divides the interpersonal rapport dimension into high (warm, open, predictable, and highly student-oriented), medium (relatively warm, approachable, democratic, and predictable), and low (cold, distant, highly controlling, unpredictable). To interpersonal rapport we have added a fourth level below low—punishing (attacking, sarcastic, disdainful, controlling, and unpredictable)—since we

TABLE 1-1 TWO-DIMENSIONAL MODEL OF TEACHING (Modified from Lowman, 1985)

Intellectual Excitement	Interpersonal Rapport			
	Punishing	**Low**	**Moderate**	**High**
High	6'. Intellectual Attacker	6. Intellectual Authority	8. Masterful Lecturer	9. Complete Master
Moderate	3'. Adequate Attacker	3. Adequate	5. Competent	7. Masterful Facilitator
Low	1'. Inadequate Attacker	1. Inadequate	2. Marginal	4. "Warm fuzzy"

have observed professors in this category.

The numbering system in Table 1-1 indicates that professors improve their teaching much more quickly by increasing their intellectual excitement than by developing greater rapport with students. For example, a professor who is high in interpersonal rapport and low in intellectual excitement (position 4) will be considered a poorer teacher than a professor who is high in intellectual excitement and low in interpersonal rapport (position 6). Because their strengths are very different, these two teachers will excel in very different types of classes. The professor in position 4 will do best with a small class with a great deal of student participation, whereas the professor in position 6 will do best in large lecture classes. Our impression based on a very unscientific sample is that most engineering professors are in the broad moderate level of intellectual excitement and are at all levels of interpersonal rapport. The difference between these teachers and those at the high level of intellectual excitement is that the latter either consciously or unconsciously pay more attention to the performance aspects of teaching. Fortunately, all engineering professors can improve their teaching in both dimensions, and position 5 (competent) is accessible to all. Although becoming a complete master is a laudable goal to aim for, teachers who have attained this level are rare.

Hanna and McGill (1985) contend that the affective aspects of teaching are more important than method. Affective components which appear to be critical for effective teaching include:

- Valuing learning
- A student-centered orientation
- A belief that students can learn
- A need to help students learn.

These affective components are included in the model in Table 1-1. High intellectual excitement is impossible without valuing the learning of content and a need to present the material in a form which aids learning. High interpersonal rapport requires a student-centered orientation and a belief that students can learn.

A few comments about the punishing level of interpersonal rapport are in order. Since most students will fear such a professor, they will do the course assignments and learn the material if they remain in the course and aren't immobilized by fear. However, even those who do well will dislike the material. In our opinion and in the opinion of the American Association of University Professors (see Table 17-3), this punishing behavior is unprofessional. The only justification for a punishing style is to train students for a punishing environment such as that confronted by boxers, POWs, sports referees, and lawyers. Professors who stop attacking students immediately move into the level of low interpersonal rapport and receive higher student ratings.

1.3. PHILOSOPHICAL APPROACH

Teaching is an important activity of engineering professors, both in regard to content and in relation to students. New professors are usually superbly trained in content, but often have

very little idea of how students learn. This book is based on what may possibly be a revolutionary hypothesis: Young professors will do a better job teaching initially if they receive education and practice in teaching while they are graduate students or when they first start out as assistant professors. They will be more efficient the first few years and will have time for other activities.

The teaching methods covered in this book go beyond the standard lecture format, although it too is covered. Unfortunately, for too many teachers lecturing is often synonymous with teaching. In an attempt to broaden the reader's repertoire of teaching techniques, we include other teaching methods which may be more appropriate for some courses. Because advising and tutoring are closely tied to teaching, we also include these one-to-one activities. And since we believe that learning to become a good problem solver and learning how to learn are two major goals of engineering education, we also cover methods for teaching students to attain these goals.

Engineering professors invariably serve as models of proper behavior. Thus, an engineering professor should be a good engineer both technically and ethically, not using his or her position to persecute or take advantage of students. We agree with Highet (1976, p. 79) that in general students are likely to be immature and that "our chief duty is not to scorn them for this inability to comprehend, but to help them in overcoming their weakness." A well-developed sense of fairness is almost uniformly appreciated by students.

Our position on human potential is that people want to learn. Therefore, we search for ways to stop demotivating students while realizing that a few discipline problems always exist. Teaching is an important activity of engineering professors. Since they must also be involved in varying amounts of research, administration, advising, committee work, consulting, and so forth, we emphasize both effectiveness and efficiency.

1.4. WHAT WORKS: A COMPENDIUM OF LEARNING PRINCIPLES

Throughout this book we will base teaching methods on known learning principles. Many comments on what works in teaching are scattered throughout. In this section we will list many of the methods that are known to work. The ideas in this section are based on Chapters 13 to 15, papers by Chickering and Gamson (1987), Durney (1973), Irey (1981), and Wales (1976), books by Lowman (1985), Elbow (1986), McKeachie (1986), and Peters and Waterman (1982), and the government brochure *What Works* (1986).

1 Guide the learner. Be sure that students know the objectives. Tell them what will be next. Provide organization and structure appropriate for their developmental level.

2 Develop a structured hierarchy of content. Some organization in the material should be clear, but there should be opportunities for the student to do some structuring. Content needs to include concepts, applications and problem solving.

3 Use images and visual learning. Most people prefer visual learning and have better

retention when this mode is used. Encourage students to generate their own visual learning aids.

4 Ensure that the student is active. Students must actively grapple with the material. This can be done internally or externally by writing or speaking.

5 Require practice. Learning complex concepts, tasks, or problem solving requires a chance to practice in a nonthreatening environment. Some repetition is required to become both quick and accurate at tasks.

6 Provide feedback. Feedback should be prompt and, if at all possible, positive. Reward works much better than punishment. Students need a second chance to practice after feedback in order to benefit fully from it.

7 Have positive expectations of students. Positive expectations by the professor and respect from the professor are highly motivating. Low expectations and disrespect are demotivating. This is a very important principle, but it cannot be learned as a "method." A master teacher truly believes that her or his students are capable of great things.

8 Provide means for students to be challenged yet successful. Be sure students have the proper background. Provide sufficient time and tasks that everyone can do successfully but be sure that there is a challenge for everyone. Success is very motivating.

9 Individualize the teaching style. Use a variety of teaching styles and learning exercises so that each student can use his or her favorite style and so that each student becomes more proficient at all styles.

10 Make the class more cooperative. Use cooperative group exercises. Stop grading on a curve and either use mastery learning or grade against an absolute standard.

11 Ask thought-provoking questions. Thought-provoking questions do not have to have answers. Posing questions without answers can be particularly motivating for more mature students.

12 Be enthusiastic and demonstrate the joy of learning. Enthusiasm is motivating and will help students enjoy the class.

13 Encourage students to teach other students. Students who tutor others learn more themselves and the students they tutor learn more (*What Works*, 1986). In addition, students who tutor develop a sense of accomplishment and confidence in their ability.

14 Care about what you are doing. The professor who puts teaching "on automatic" cannot do an outstanding job.

15 If possible, separate teaching from evaluation. If a different person does the evaluation, the teacher can become a coach and ally whose goal is to help the student learn.

1.5. CHAPTER COMMENTS

At the end of each chapter we will step aside and look philosophically at the chapter. These "metacomments" allow us to look at teaching from a viewpoint that is "outside" or "above" the teacher. In class we use metadiscussion to discuss what has happened in class. In this chapter we set up a strawman who argued against courses on teaching methods and then knocked him down. The strawman is real in some universities, and we have met him many

times while developing the course this book is based on. This book is written in a pragmatic, how-to-do-it style. There are philosophical and spiritual aspects of teaching which are given little attention. A good counterpoint to this book is Palmer's (1983) book on the spiritual aspects of education.

1.6. SUMMARY AND OBJECTIVES

After reading this chapter, you should be able to:

- Discuss the goals of this book.
- Answer the comments of critics.
- Explain the two-dimensional model of teaching.
- Discuss some of the values which underlie your ideals of teaching.
- Explain some applications of learning principles to engineering education.

HOMEWORK

1 Many additional critical comments can be made about the need for a teaching course. Develop both a critical comment and your response to this comment.
2 Good teachers must remain intellectually active. Brainstorm at least a dozen ways a professor can do this during a forty-year career.
3 Discuss the values which influence your teaching.
4 Determine the positions in Table 1-1 of engineering professors you have had as an undergraduate or graduate student. What could these professors have done to improve their teaching? (If this assignment is turned in, do not identify the professor by name.)

REFERENCES

ASEE, "Quality of Engineering Education Project," *Eng. Educ.,* 153 (Dec. 1985).Durney, C. H., "A review: Principles of design and analysis of learning systems," *Eng. Educ.*, 406 (March 1973).

Chickering, A. W. and Gamson, Z. F., "Seven principles for good practice in undergraduate education," *AAHE Bull.,* 3 (March 1987). (AAHE is the American Association for Higher Education.)

Elbow, P., *Embracing Contraries: Explorations in Learning and Teaching,* Oxford University Press, New York, Chapter 7, 1986.

Felder, R. M., Leonard, R., and Porter, R. L., "Oh God, not another teaching workshop," *Eng. Educ.*, 622 (Sept./Oct. 1989).

Hanna, S. J. and McGill, L. T., "A nurturing environment and effective teaching," *Coll. Teach.*, 33(4), 177 (1985).

Highet, G., *The Immortal Profession: The Joys of Teaching and Learning,*Weybright and Talley, New York, 1976.

Hodgkinson, H. L., "All One System. Demographics of Education: Kindergarten Through Graduate School, " The Institute for Leadership, Washington, DC, 1985 (pamphlet).

Irey, R. K., "Four principles of effective teaching," *Eng. Educ.,* 285 (Feb. 1987).

Lowman, J. *Mastering the Techniques of Teaching,* Jossey-Bass, San Francisco, 1985.

McKeachie, W. J., *Teaching Tips,* 8th ed., D.C. Heath, Lexington, MA, 1986.

Palmer, P. J., *To Know as We Are Known: A Spirituality of Education,* Harper Collins, San Francisco, 1983.

Peters, T. J. and Waterman, R. H., Jr., *In Search of Excellence: Lessons from America's Best-Run Companies*, Harper and Row, New York, 1982.

Reynolds, W. A. and Oaxaca, J. (Co-chairs), "Changing America: The new face of science and engineering," Interim Report of the Task Force on Women, Minorities, and the Handicapped in Science and Technology, Washington, DC, 1988.

Stice, J., "The need for a 'how to teach' course for graduate students," *Proceedings ASEE Annual Conference*, ASEE, Washington, DC, 65, 1991.

Van Ness, H. C., "Chemical engineering education: Will we ever get it right?" *Chem. Eng. Prog.,* 85 (1), 18 (Jan. 1989).

Wankat, P. C. and Oreovicz, F. S., "Teaching prospective faculty members about teaching: A graduate engineering course," *Eng. Educ.*, 84 (1984).

Wales, C. E., "Improve your teaching tomorrow with teaching-learning psychology," *Eng. Educ.,* 390 (Feb. 1976).

Wentzel, H. K., "Seminars in college teaching: An approach to faculty development." *Coll. Teach.,* 35, 70 (1987).

What Works, U.S. Department of Education, Washington, DC, 1986. (Copies can be obtained by writing to *What Works,* Pueblo, CO, 81009).