CHAPTER 4

COURSES: OBJECTIVES AND TEXTBOOKS

What content should be covered in a course? This is obviously a critical question for required courses which are prerequisites for other courses. The answer also depends upon departmental values. In this chapter we will discuss setting goals and objectives for a course, taxonomies of knowledge, the interaction between teaching styles and objectives, development of the content of a course, and finally textbooks.

4.1. COURSE GOALS AND OBJECTIVES

Goals are the broad final result that one hopes to attain during a course. Usually they are stated in broad, general terms. For example, in a thermodynamics course one's goals might be that students should be able to:

- Solve problems using the first law.
- Solve problems requiring use of the second law.
- Understand the limitations of thermodynamics.
- Appreciate the power and beauty of thermodynamics.

Note that content comes first. Engineering education is centered on content, and goals and objectives should focus on content (Plants, 1972). General goals such as these are nonspecific and thus are often fairly easy to agree upon. However, goals are not specific enough to be useful in an operational sense except as an overall guide.

Goals provide an overall guide for what a course is supposed to do. They are helpful to the department in designing the curriculum, to the professor in delineating the boundaries of the class, and to students (particularly intuitive and global learners) in seeing where the class is going. For example, if the department can agree that classical thermodynamics is the goal of the course, then the professor knows that he or she is not expected to cover statistical thermodynamics or irreversible thermodynamics. Professors teaching follow-up courses will know that students who have taken the classical thermodynamics course will not have a background in these subjects. Clearly, this also implies a certain amount of communication and collegiality which does not exist in all departments. Students can look at the curriculum and tell where the course fits. Of course, many students will not bother to do this, but the goals are helpful for those students who do.

Goals can be considered to be global objectives. More specific objectives are useful to guide both the professor and the student in exactly what students will learn, feel, and be able to do after each section of the course is completed. One such popular type of objective is the behavioral objective (Hanna and Cashin, 1987; Mager, 1962; Kibler et al., 1970; Stice, 1976). A behavioral objective states explicitly:

1 What the student is to do (i.e., the behavior).
2 The conditions under which the behavior is to be displayed.
3 The level of achievement expected.

Writing a few behavioral objectives for a class forces the professor to think about observable behavior, conditions, and level of performance. However, we do not know any engineering professors who write out complete behavioral objectives for all their classes. Here is an example of a possible, though cumbersome, behavioral objective for a thermodynamics course:

The student will be able to write down on a piece of paper the analysis to determine the new Rankine cycle performance when the maximum cycle temperature and pressure are changed. This will be done in a timed fifteen-minute in-class quiz, and the student is expected to obtain the correct answer within 1 percent.

Professors who use objectives invariably use a shortened version. In this form the previous objective becomes:

Analyze the effect of maximum cycle temperature and pressure on the performance of a Rankine cycle.

This form is easier to write, focuses on content, and is more likely to be read by students. Hanna and Cashin (1987) discuss the different types of educational objectives, noting that behavioral objectives are usually written in the form of the minimal essential objective, and that these objectives focus on relatively low-level skills since such skills are easiest to measure. For the higher-level skills which practicing engineers need, behavioral indicators of achieve-

TABLE 4-1 EXAMPLES OF THERMODYNAMICS OBJECTIVES

1. The student can write the first and second laws.
2. The student can describe the first and second laws in his or her own language. (That is, describe these laws to the student's grandmother.)
3. The student can solve simple single-answer problems using the first law.
4. The student can solve problems requiring both the first and second laws either sequentially or simultaneously.
5. Given the characteristics of a standard compressor, the student can develop schemes to compress a large amount of gas to a high pressure where both the amount of gas and the required pressure increase are larger than a single compressor can handle.
6. The student can use the second law to determine fallacies in power cycles. The student can describe the fallacies clearly and logically both in memos and in oral debate.
7. The student understands the limits of his or her knowledge and knows when classical thermodynamics is not the appropriate analysis tool.
8. The student can evaluate his or her own solutions and those of others to find and correct errors.
9. The student can search appropriate data bases and the literature to find required thermodynamic data, and if the data are not available the student can select appropriate procedures and predict the values of the data.
10. Since one of the goals of this course is to help students become broadly educated, the student can appreciate the beauty of classical thermodynamics and can briefly outline the history of the field.

ment without minimum standards are more appropriate. For these objectives, student behaviors are illustrations only. Minimum standards are not given since students are encouraged to do the best they can. Conditions for performance are explicitly stated, but this may be done for an entire set of objectives and may be considered to be understood. A set of content-oriented related examples for a thermodynamics course is given in Table 4-1.

Objectives aid the instructor since they clarify the important content to be covered in readings, lectures, homework, and tests. If material is not important enough to have an objective, then it should be omitted. When developing tests, the professor can look at the list of objectives and check that the most important are included in the test questions. This procedure is discussed further in Chapter 11.

Objectives should be shared with students so that they know what material to study and what material they will be tested on (DeBrunner, 1991). Students should also be explicitly told if other skills, such as those involving a computer or communication, will be required in the course. And they should know if they are expected to become broadly educated in the field and be able to do more than just solve problems. Examples of both these areas are included in the set of thermodynamics objectives. These objectives are written at several different levels. It is important to ensure that the course objectives and hence readings, lectures, homework, and tests cover the range of levels desired. The appropriate levels and types of objectives are included in taxonomies.

4.2. TAXONOMIES OR DOMAINS OF KNOWLEDGE

Taxonomies of educational objectives were created by two very significant committee efforts in the 1950s and early 1960s. The taxonomy in the cognitive domain (Bloom et al., 1956), which includes knowledge, intellectual abilities and intellectual skills, has been widely adopted, whereas the taxonomy in the affective domain (Krathwohl et al., 1964), which includes interest, attitudes, and values, has had less influence. A third domain is the psychomotor, manipulative, or motor skills area. This area appears to be continuously decreasing in importance in engineering education, although the success of graduate students doing experimental research often depends on this domain. A problem-solving taxonomy has also been developed by engineering educators. These taxonomies are discussed in the following four sections.

4.2.1. Cognitive Domain

Since the cognitive domain is involved with thinking, knowledge, and the application of knowledge, it is the domain of most interest to engineering educators. Bloom et al. (1956) divided the domain into six major levels and each level into further subdivisions. The six major divisions appear to be sufficient for the purposes of engineering education.

1 Knowledge. Knowledge consists of facts, conventions, definitions, jargon, technical terms, classifications, categories, and criteria. It also consists of the ability to recall methodology and procedures, abstractions, principles, and theories in the field. Knowledge is necessary but not sufficient for solving problems. Examples of knowledge that might be required include knowing the values of e and π, knowing the sign conventions for heat and work in an energy balance, knowing the definition of irreversible work, knowing what a quark is, being able to list the six areas of the taxonomy of educational objectives, defining the scientific method, and recalling the Navier-Stokes or Maxwell equations. The potential danger in the knowledge level is that it is very easy to generate test questions, particularly multiple-choice questions, at this level. The ability to answer these questions correlates with a student's memorization skills but not with his or her problem-solving skills. In some areas of science such as biology, students are expected to memorize a large body of knowledge, but this is unusual in engineering. The first objective in Table 4-1 is an example of a knowledge objective.

2 Comprehension. Comprehension is the ability to understand or grasp the meaning of material, but not necessarily to solve problems or relate it to other material. An individual who comprehends something can paraphrase it in his or her own words. The information can be interpreted, as in the interpretation of experimental data, or trends and tendencies can be extended or extrapolated. Comprehension is a higher-order skill than knowledge, but knowledge is required for comprehension. Testing for comprehension includes essay questions, the interpretation of paragraphs or data (this can be done with multiple-choice) or oral exams. The second objective in Table 4-1 is an example of an objective at the comprehension level.

3 Application. Application is the use of abstract ideas in particular concrete situations. Many straightforward engineering homework problems with a single solution and a single part fit into this level. Application in engineering usually requires remembering and applying technical ideas, principles, and theories. Examples include determining the pressure for an ideal gas, determining the cost of a particular type of equipment, determining the flow in a simple pipe, determining the deviation of a beam to a load, and determining the voltage drop in a simple circuit. Objective 3 in Table 4-1 is an example.

4 Analysis. In engineering, analysis usually consists of breaking down a complex problem into parts. Each part can then be further broken down or be solved by application of engineering principles. The connections and interactions between the different parts can be determined. Objective 4 in Table 4-1 is an example of an analysis objective since it requires breaking a more complex problem into parts and then determining the relationship between the parts. Many engineering problems fall into the analysis level because very complicated engineering systems must be analyzed.

5 Synthesis. Synthesis involves taking many pieces and putting them together to make a new whole. A major part of engineering design involves synthesis. One problem for the professor in teaching synthesis is that there is no longer a single correct answer. Many students, particularly at the lower levels in Perry's scheme of intellectual development (see Chapter 14), find synthesis difficult because the process is open-ended and there is no single answer. Synthesis should be incorporated into every course and not be delayed until the "capstone" senior design course. Objective 5 in Table 4-1 is an example of a synthesis problem for a thermodynamics course.

6 Evaluation. Evaluation is a judgment about a solution, process, design, report, material, and so forth. The judgment can be based on internal criteria. Is the solution logically correct? Is the solution free of mathematical errors? Is the report grammatically correct and easy to understand? Is the computer program documented properly? Objectives 6 and 8 in Table 4-1 are examples of objectives at the evaluation level which use internal criteria. Objective 7 is also an evaluation example based on internal evidence but is easier to attain if external sources are also utilized. In this case the external sources would be some knowledge of statistical thermodynamics and irreversible thermodynamics. In many engineering problems the evaluation requires external criteria such as an analysis of both economics and environmental impact. Objective 9 in Table 4-1 requests evaluation using external criteria, and it also requests analysis.

Bloom's taxonomy is a hierarchy. Knowledge, comprehension, application, and analysis are all required before one can properly do synthesis. It can be argued that in engineering, synthesis is a higher-order activity than evaluation, since evaluation is needed to determine which of many answers is optimum. Without getting into this argument, note that students need practice and feedback on all levels of the taxonomy to become proficient. The major use of the taxonomy for professors is to ensure that objectives, lectures, homework, and tests include examples and problems at all levels. Stice (1976) noted that when he classified the test questions in one of his classes he was horrified to find that almost all of them were in the three lowest levels of Bloom's taxonomy. Since students tend to learn what they are tested for, most of the students were not developing higher-level cognitive skills in this class. If the teaching style, homework, and test questions are suitably adjusted, students can be taught content at all levels of the taxonomy.

4.2.2. Affective Domain

The affective domain is concerned with behaviors and objectives which are emotional and deal with feelings. It includes likes and dislikes, attitudes, value systems, and beliefs. Development of a taxonomy for the affective domain proceeded in a parallel but slower fashion than for the cognitive domain. There was overlap on the two development committees, and the logic in developing the taxonomies was similar. However, the taxonomy in the affective domain was much more difficult to develop because there is much less agreement on the hierarchical structure. Krathwohl et al. (1964) used the process of internalization to describe the hierarchical structure of learning and growth in the affective field. Internalization is similar to socialization and refers to the inner growth as an individual adopts attitudes, principles, and codes to guide his or her value judgments. The affective domain taxonomy has had considerably less influence in education than the cognitive domain taxonomy. This is particularly true in engineering education, perhaps because of the large number of thinking types in engineering (see Chapter 13). The five levels of the affective domain are briefly outlined below (Kibler et al., 1970; Krathwohl et al., 1964).

1 Receiving and attending. Is the individual aware of a particular phenomenon or stimulus? Is he or she willing to receive the information or does he or she automatically reject it? Does the individual choose to pay attention to a particular stimulus? Information above the individual's level of intellectual development may not be attended to because it cannot be understood.

2 Responding. The individual is willing to respond to the information. This occurs first as passive compliance when someone else initiates the behavior. Then the individual becomes willing to and desires to respond on his or her own initiative. Finally, the response leads to personal satisfaction which will motivate the individual to make additional responses.

3 Valuing. The individual decides that an object, phenomenon, or behavior has inherent worth. The individual first accepts the value, then prefers the value, and finally becomes committed to the value as a principle to guide behavior.

4 Organization. The individual needs to organize values into a system, determine how they interrelate, and establish a pecking order of values.

5 Characterization by a value. The individual's behavior becomes congruent with his or her value structure, and the individual acts in a way that allows others to see his or her underlying values. Many modes of common speech point to people who are characterized by their values: "She is a caring person." "He always puts students first." "He is very up-front."

The affective domain has not been heavily studied or discussed in engineering education, yet engineering professors do have value goals for their students. They want them to be honest, hard-working, ethical individuals who study engineering because of an intrinsic desire for knowledge. Perhaps there would be a little more movement toward these goals if professors explicitly stated some of their expectations and objectives in this domain. One example is the use of an honor code. A second example is objective 10 in Table 4-1.

4.2.3. Psychomotor Domain

The psychomotor domain includes motor skills, eye-hand coordination, fine and major muscle movements, speech, and so forth. The importance of this domain in engineering education has been continually decreasing as shop courses have been removed, calculators have replaced slide rules, and digital meters have replaced analog meters. Psychomotor skills are still useful in engineering education, particularly for graduate students doing experimental research. Examples include reading an oscilloscope, glassblowing, welding, turning a valve in the correct direction, soldering, titration, typing and keyboarding numbers on a calculator, gestures while speaking, and proper speech.

The taxonomy in the psychomotor domain includes (Kibler et al., 1970):

1 Gross body movements.
2 Finely coordinated body movements.
3 Nonverbal communication behaviors.
4 Speech behaviors.

Finely coordinated body movements include typing and keyboarding. Because of the importance of computers and calculators in the practice of engineering, these psychomotor skills have become much more important than in the past. We feel strongly that all engineers should learn these skills.

Nonverbal communication skills are very important to actors. Salespeople probably need to study these skills also. If an engineer is interested in technical sales, some development of these skills may be helpful. For other engineers, including engineering professors, nonverbal communication needs to be congruent with the spoken message. Individuals can be successful engineers with speech handicaps. However, the ability to talk clearly and distinctly and to project one's voice is a distinct aid to communication. In addition, communication can be enhanced by coordinating facial expressions, body movement, gestures, and verbal messages (see Chapter 14). Professors who desire to become outstanding lecturers need to develop their skills in speech behaviors (see Chapter 6).

4.2.4. Problem-Solving Taxonomy

A taxonomy for problem solving was developed by Plants et al. (1980). This taxonomy was published in the engineering education literature and has not been as widely distributed or adopted as the other taxonomies. Because of the importance of problem solving in engineering education, this taxonomy can be useful. Applications of the problem-solving taxonomy to engineering education are discussed in Chapter 5, by Plants (1986, 1989), and by Sears and Dean (1983). The five levels of the taxonomy are briefly discussed below.

1 Routines. Routines are operations or algorithms which can be done without making any decisions. Many mathematical operations such as solution of a quadratic equation, evaluation of an integral, analysis of variance, and long division are routines. In Bloom's taxonomy these would be considered application-level problems. Students consider these "plug-and-chug" problems.

2 Diagnosis. Diagnosis is selection of the correct routine or the correct way to use a routine. For example, many formulas can be used to determine the stress on a beam, and diagnosis is selection of the correct procedure. For complex integrations, integration by parts can be done in several different ways. Selecting the appropriate way to do the integration by parts involves diagnosis. This level obviously overlaps with the application and analysis levels in Bloom's taxonomy.

3 Strategy. Strategy is the choice of routines and the order in which to apply them when a variety of routines can be used correctly to solve problems. Strategy is part of the analysis and evaluation levels of Bloom's taxonomy. The strategy of problem solving and how to teach it are the major topics of Chapter 5.

4 Interpretation. Interpretation is real-world problem solving. It involves reducing a real-world problem to one which can be solved. This may involve assumptions and interpretations to obtain data in a useful form. Interpretation is also concerned with use of the problem solution in the real world.

5 Generation. Generation is the development of routines which are new to the user. This may involve merely stringing together known routines into a new pattern. It may also involve creativity in that the new routine is not obvious from the known information. Creativity is also a topic of Chapter 5.

4.3. THE INTERACTION OF TEACHING STYLES AND OBJECTIVES

Once the content and objectives have been chosen, appropriate teaching methods can be selected. To meet any of the objectives (including the affective objectives), students must have a chance to practice and receive feedback. If you want them to meet certain objectives, share these objectives with them and test for these objectives. Students will work to learn the stated objectives in the course. If the objectives are not stated and are unclear, they will work to learn what they think the objectives are. This is much more of a hit-and-miss proposition than stating clear objectives.

The importance of clear objectives is highlighted by research on teaching styles and student learning (Taveggia and Hedley, 1972). Student learning of subject matter content as measured by course content examinations is essentially the same regardless of the teaching style as long as the students are given clear, definite objectives and a list of materials for attaining the objectives. Note that this applies to the knowledge, comprehension, application, and perhaps analysis levels, but not to synthesis, evaluation or problem solving.

Most of the time in engineering classes is spent trying to teach cognitive content objectives. Knowledge-level objectives and content are the easiest to teach and test for. Knowledge-level material can be learned from well-written articles, books, and class notes. If the objectives are clear, students will memorize the material. For example, if a student reading this book is told to learn the six levels of the cognitive domain, he or she will memorize them. Lecture can also be used for transmission of knowledge-level material, but it is less effective than written material except for clarifying questions. Comprehension is a higher level than knowledge, and more student activity can be useful. Written material is useful, particularly if the student paraphrases the material or develops his or her own hierarchical structure. To be effective, lectures need to have reasonable amounts of discussion and/or questions so that students actively process the material. Discussion and groups can also be helpful for comprehension, as can homework and problem solving.

Applications in engineering usually means problem solving. It is useful to show some solutions in class, but there is the danger that the solutions shown may be too neat and sterile since the professor has removed all the false starts and mistakes (see Chapter 5). Watching someone else solve problems does not make a student a good problem solver: The student must solve problems. A good starting point is homework with prompt feedback and with the requirement that incorrect problems be reworked. Group problem solving both in and out of class is a good teaching method since the interactions help many students. Tutoring and teaching are also excellent methods for mastering application objectives since tutoring and teaching require one to structure the knowledge. Analysis objectives usually involve more complex problems and can be taught by the same methods used for application.

To learn to do synthesis one must do synthesis. This can be started in the freshman year in computer programming courses. Once students have mastered application and analysis, they can synthesize a large program by combining already created parts and new parts. Group work can again be valuable since it helps motivate students and increases retention (Hewitt, 1991). Synthesis in upper-division classes often involves developing a new design, whether it is an integrated circuit, a chemical plant, a nuclear reactor, or a bridge. Creativity can be encouraged by providing computer tools which will do the routine calculations. The PMI approach (see Section 5.6.3) which finds pluses, minuses, and interesting aspects of the proposed solution is useful in encouraging students to be creative in synthesis.

Evaluation is not something that only the professor should do. Students need to practice this skill since they will be expected to be able to evaluate as practicing engineers. The professor can demonstrate the skill in class, have the students practice evaluation, and provide feedback on their evaluations. One way to do this is to show an incorrect solution on an overhead transparency. After giving the students a few minutes to study the solution, the professor can grade the solution while it is on the overhead. The students can then be given several solutions to evaluate as homework. At least one of these solutions should be correct since part of evaluation involves recognizing correct solutions. The students' papers are then turned in and graded. A slight twist to this is to return student homework or tests with no marks and tell the student to evaluate and correct the paper before turning it in for a grade.

Engineering professors can help students master objectives in the affective domain by sharing the explicit objectives with them in a positive fashion. For example, an instructor might say, "Since you all expect to become practicing engineers, I expect you to demonstrate professional behavior and ethical standards in this class." This is preferable to saying, "If I catch any of you cheating I am going to prosecute you and force you out of engineering."

Short (and be sure they are short) "war stories" during lectures can be helpful in helping students socialize and internalize the engineering discipline (this socialization is usually a major unstated affective objective). Engineering experience through co-op, internships, and summer jobs is an excellent way to socialize engineering students if the experience is positive. Enjoyment of the class is one of our affective objectives. A professor who is pleasant, greets students by name, and is both fair and reasonable to them is likely to have students who enjoy the class.

Psychomotor objectives require practice of the skills. Most of these can be done in laboratory, but the professor needs to be aware that students may need instruction in some simple manual manipulations. Groups are effective since one member of the group often already possesses the psychomotor skills. Few engineering professors are trained to work with students who have major deficits in the psychomotor area. Since psychomotor problems, particularly in speech, can cause both students and practicing engineers major difficulties, engineering professors should know what resources are available for help.

4.4. DEVELOPING THE CONTENT OF THE COURSE

The content of each course in the curriculum is the topic of many faculty discussions. We do not intend to discuss disciplinary details since that is not the purpose of this book. Instead, we will briefly explore some pedagogical details. In required courses the content must make the course fit into the curriculum.

Although there is never complete unanimity, most engineering departments generally agree on the content a student must have before completing his or her degree. This content must appear somewhere in the curriculum. In addition, required courses often serve as prerequisites for other courses, and the appropriate prerequisite material must be covered. The only way to ensure that the expected content is covered is to communicate with other faculty. Find out what is needed for other courses. Discuss in detail what material the students have had in prerequisite courses and find out what they are capable of doing after they have passed the prerequisite courses. (Obviously, what a student can do is not necessarily the same as what the professor covered.) Discuss the outline with other faculty who have taught the course in the past or who might want to teach it in the future. Before making major course revisions or before changing the textbook be sure that critical material is not deleted. Talk to engineers in industry to determine what they use and do not use. Update the content you use so that it is in computer-accessible form. This will avoid discouraging students from using computers.

Once the major content for the course has been outlined, look at the hierarchy of objectives you wish to cover. The time required for each topic depends on the depth of your coverage and on the objectives, in addition to the beginning knowledge of the students. A well-thought-out textbook will have done this, but you may disagree with some of the author's decisions. Plan the level of presentations considering the students' maturity (see Chapter 14). Then you can plan the major objectives for each lecture.

We suggest that the bulk of the course be developed for the sensing types (see Chapter 13) and serial learners in the class. Following a logical development makes it much easier for these students to learn the material, and this sequence does not hamper the intuitive types and the global learners. Sensing types will appreciate examples and concrete applications. At the beginning and/or end of each class include the global picture for intuitive types and global learners. Intersperse theory with applications to keep both the intuitive and sensing types interested. Include both visual and kinesthetic material. Conscious use of a learning cycle will increase student learning. This arrangement will ensure that every student has part of the course catered to his or her strengths, but that the student will also be encouraged to strengthen his or her weaknesses.

4.5. TEXTBOOKS

Textbooks are commonly used in undergraduate engineering education in the United States. Selection of a textbook is important since it can add or subtract from the course quality and because many engineers keep their textbooks and use them as a primary reference for many years. Useful discussions on textbook selection are included in Eble (1988), Johnson (1988), and Plants et al. (1973).

4.5.1. Should a Textbook Be Used?

The advantages of a well-written textbook are that it provides content at the appropriate level in a well-structured form with consistent nomenclature and includes appropriate learning aids such as example problems, objectives, figures, tables, and homework problems at a variety of levels of difficulty. The disadvantages are that a textbook usually provides only one viewpoint, may not include the content you want, may be out of date, and may not be the ideal format for helping students learn to learn on their own.

In beginning courses students often want and need the structure that a good textbook provides. Since basic knowledge is not changing rapidly, textbooks at this level do not become obsolete rapidly; and because of the numerous pressures to standardize lower division courses [e.g., transferring of credits, ABET requirements (see Section 4.6), "standard" textbooks, and movement of faculty between schools], textbooks which closely match the requirements of these courses are usually available. If an appropriate textbook is not available, then a publish-on-demand textbook can be considered (see Section 4.5.3). The result is that textbooks are usually used for required undergraduate courses, particularly lower-division courses.

The situation is often different for undergraduate elective courses and all courses at the graduate level. A book for a specialized course may not exist. Books for courses at the frontiers of knowledge can rapidly become obsolete. Since the market for these books is smaller than for required undergraduate courses, there will be fewer books to choose from and they will be more expensive. Seniors and graduate students need less structure and can better cope with varying author styles and different nomenclatures. The original literature is not as efficient a way to teach since it was not written for students, but it is a good vehicle to help students learn how to learn on their own. The original literature can often provide a sense of excitement which is missing from most textbooks. Thus, it may be appropriate to assign readings from the original literature. Is the cost of the textbook reasonable? Many engineering textbooks, particularly at advanced levels, are not reasonably priced, and this may be a reason to use readings from the original literature. However, copyright law is in flux and professors need to be cautious when making a number of copies of copyrighted material for a class. Permission must be obtained from the copyright owners before making copies. A good source of information on this issue is the National Association of College Stores (1991) brochure.

A good textbook can be a tremendous aid and save a great deal of time. By developing the book for a course, the author has already done much of the organization and presentation of content for you. But books do limit what you can do in a class. Students won't mind if you occasionally skip around in the textbook or require other readings. However, if this is done extensively, they will become annoyed and wonder why you have made them buy an expensive book and then never use it.

4.5.2. Textbook Selection

To some students textbooks develop an almost mystical importance. The book is treated as if it contains **The Truth**. Perhaps this is a carry over from the monastic beginnings of universities where students studied "sacred texts" (Palmer, 1983). Because of this devotion of many students, textbook selection is important. An unnecessarily difficult textbook will discourage, excessive errors can lead to a loss of faith, and an obsolete textbook serves students poorly.

Intelligent choice of a textbook requires a significant amount of effort. If nomenclature and jargon are standard in your area, you can obtain a good feel for content coverage by looking at the table of contents. The most recent copyright date can tell if recent advances might be included, but not all authors of undergraduate textbooks are up-to-date with research. You'll have to delve into a few chapters to make sure the ideas are current. A convenient way of comparing a number of books is to check a few key items that you will cover in your course.

You'll also need to read some sections to see if the author's writing style will be understandable to your students. Although you can assume that most authors of engineering textbooks understand the content, you cannot assume that they understand how students learn. An inductive approach starting with specifics and leading to generalities is much more appropriate in an introductory textbook than an deductive approach. For introductory courses, books written in a concrete instead of an abstract style are also easier for most students to understand. Sensing students particularly appreciate detailed examples. Explicitly listing objectives is also helpful to tell students what they are expected to be able to do. The writing should be at a level appropriate for the students, and new jargon should be carefully defined. Figures and tables should be clearly labeled so that nothing needs to be assumed to understand them. Relatively short sections are easier for most students since there is a sense of accomplishment when each section is completed. Intuitive students may use the section headings and subheadings to obtain an overview of the chapter contents, so it is important that these give a true picture of the organization of the content. Homework problems should be clear and unambigious. It is also helpful if the level of difficulty of the problems is indicated. If possible, examine the solutions manual since it is often a good guide to how carefully the homework problems have been crafted. The absence of a solutions manual may indicate that the author did not spend much time on the homework problems. Books using a deductive approach or written in an abstract style with few examples may be appropriate for advanced-level classes where students are seeing the material for a second time.

A careful check of content versus your preferred course outline is necessary. Does the sequence of material make sense? Skipping around in the book is often confusing to students. If the book has light coverage of some topics, you may have to supplement it with course notes and/or outside reading. If some topics are explained in insufficient detail, you may be able to compensate in lecture. And if the book has extra material that the course will not cover, you need to determine how easy it will be to skip sections. Some authors clearly state the prerequisite chapters for each chapter so that users know which sections can be skipped. Other authors provide supplemental sections of optional material. While looking at the content, check for typographical errors and fundamental mistakes. Not all books are created equal with respect to accuracy. Typographical errors, particularly in example problems, can be extremely confusing to students who have not yet learned how to evaluate the material for correctness. Such errors may also undermine the book's credibility with students.

Is there supplemental material which will help you teach the course? If you will be teaching a course that is not your major interest, a solutions manual which correctly solves problems will be helpful. If the course is in your area of primary interest, you may choose not to use a solutions manual. Computer software bundled with the adoption of a textbook can be very advantageous if the software is compatible with the school's computer system. Some engineering textbooks integrate software into the homework assignments and the teaching of the content.

Will the book be useful to the students in later courses or as a reference after they graduate? An excellent index is not necessary when a book is used as a textbook, but it is essential for reference use. Proper referencing of appropriate source materials is also important for reference use of the book. If students will keep the book for a long period, it needs to be printed on good quality paper and be durably bound. A laboratory workbook which will probably be discarded does not need this kind of quality.

Textbook adoptions should be considered to be tentative. After a semester's use, the book can be reevaluated. Ask the students for feedback on the book. Consider how well it worked on a line-by-line and day-by-day basis. If the book does not work out or a better book becomes available, you can switch.

4.5.3. Publish-on-Demand Textbooks

The future of textbook publishing may well be publish-on-demand textbooks. McGraw-Hill, Inc., has been the innovator in this area. A fairly large book is stored on a computer. The user selects the chapters that he or she wants to use and the order in which they should appear. The computer software automatically renumbers all chapters, figure and table numbers, equation numbers, and so forth. The new book is printed out in the desired order, and the books are bound and shipped to the school. The cost is proportional to the size of the book created.

With this technology, chapters from different books and even chapters written by the professor can be included in the made-to-order book. The publisher takes care of obtaining permissions and paying appropriate royalties to the authors. Since professors customize the books, the actual number of pages each student purchases will be less and the cost will probably be less. However, there is likely to be a smaller market in used books since customized books change more often and are much less transferable from school to school. Thus, the publisher would probably sell more new copies.

However, this is a new technology and not all the problems have been resolved. The technology for ensuring that the nomenclatures of different chapters are compatible if the chapters are from different sources has not been developed. Of course, there's no guarantee that a single author will be consistent in the use of nomenclature either. Methods of combining chapters from books published by different companies have not been completely developed. Acceptance by the professoriate is also not assured.

4.5.4. Writing Textbooks

"There are bad texts—which someone else writes—good texts—which we write—and perfect texts—which we plan to write some day" (Eble, 1988). Many young professors have the goal of someday writing the classical textbook in their area of expertise. The motivation to write a textbook in engineering often arises from dissatisfaction with the textbooks which are available or the total unavailability of any textbook in a new field. Writing a textbook is difficult but rewarding work. There is personal satisfaction from having done a difficult task well, a good textbook can help an engineering professor become well known, and a successful textbook can be financially rewarding. In addition, while writing the textbook, the professor is likely to be vitally interested in the class and will probably do a good job of teaching the course.

The common wisdom is that engineering professors should wait to write a textbook until they have tenure. Sykes (1991) quotes an unidentified professor: "Nobody seeking tenure can possibly have the time to write a textbook!" The professor should have several years of teaching experience, which will be helpful in writing the textbook, and should probably be an expert (see Section 5.2). And, most importantly, because of the period of time required to complete and publish a textbook, writing one is risky for an assistant professor.

Engineering professors are not trained in all the various aspects of writing textbooks, and a certain amount of on-the-job training takes place. Fortunately, successful authors enjoy writing about writing, and there are a variety of sources of advice both for writing on engineering in particular (Beakley, 1988; Bird, 1983; Roden, 1987) and for writing books in general (Levine, 1988; Krull, 1989; Mueller, 1978). The new author can also join the Textbook Author's Association (TAA, P.O. Box 535, Orange Springs, FL 32182-0535) and benefit from the *TAA Report*. Joining TAA is particularly helpful for learning about contracts and what publishers do but not for deciding upon appropriate content. A little knowledge (such as that a 15 percent royalty on a publisher's net receipts is common for college textbooks) is very helpful when a contract is negotiated. Our advice to potential authors is simple. If writing a book is the right thing to do, do it. Signs that it is the right thing to do include:

• You've taught the course for several years, and none of the available books is really satisfactory.
• You know you can write a better book.
• You feel compelled to write a book.
• You have already written extensive handouts for the class to supplement the book you are using.
• Students ask why you haven't written a book since they are sure you can do a better job.
• You have sufficient energy and time so that the thought of another project does not make you cringe.

4.6. ACCREDITATION CONSTRAINTS ON UNDERGRADUATE PROGRAMS

Most engineering programs in the United States are accredited by the Accreditation Board for Engineering and Technology (ABET). Accreditation is considered desirable since it allows graduates to take the appropriate examinations to become a professional engineer, makes the transfer of credits to other universities easier, makes it easier for graduates to get admitted into graduate school, and serves as a stamp of approval on the quality of the program. However, accreditation does put some constraints on undergraduate engineering programs. These constraints have been the focus of considerable debate since many engineering educators believe they stifle educational innovation.

ABET's policy is to accredit individual engineering or technology programs, not an entire school. It is not unusual to have both accredited and unaccredited programs at the same university. The unaccredited programs are not necessarily poorer; instead, they may represent innovative programs that do not fit within ABET's constraints.

The ABET criteria are delineated in an ABET publication (ABET, 1989) and summarized in Table 4-2. These are minimum requirements, and individual engineering disciplines may impose additional requirements. The mathematical studies must include differential and integral calculus and differential equations. The basic sciences must include both general chemistry and general physics and may include other sciences. The engineering sciences include mechanics, thermodynamics, electrical circuits, materials science, transport phenomena, and computer science (but not programming courses). Engineering design has proven to be a controversial area and is discussed separately below. The humanities and social sciences include anthropology, economics (but not engineering economics), fine arts (but not practice-oriented courses), history, literature, political science, psychology, sociology, and foreign languages (but not speaking courses in the student's native language). The laboratory experience should be appropriate to combine elements of theory and practice. Kersten (1989) discusses the laboratory requirement in more detail. The computer-based experience should be sufficient enough so that the student can demonstrate efficiency in application and use of digital computers. Competency in written and oral communication is expected. The semester credits listed in Table 4-2 are based on a total of 128 for graduation. The requirements are adjusted if more or fewer hours are required for graduation, and the numbers are adjusted for schools on a quarter system.

Engineering design has been the most controversial area of the ABET criteria. There is no consensus on exactly what is and what is not design. Schools that see their mission as producing candidates for graduate schools or broadly educated individuals tend to want to decrease the design requirement, whereas schools producing graduates for industry want to increase the design requirement. An additional problem is that many faculty do not have industrial design experience and have difficulty teaching design.

The ABET (1989) document states that design produces a system, component, or process for specific needs. The design process is often iterative and includes decision making normally with economic and other constraints. Appropriate mathematics, science, and engineering

TABLE 4-2 SUMMARY OF ABET CRITERIA FOR ACCREDITATION OF ENGINEERING PROGRAMS

Mathematics past Trigonometry		16
Basic science		16
Engineering science		32
Engineering design		16
Humanities and social science		13
Laboratory experience		*
Computer-based experience		*
Written and oral communication		*
Other		*
	Base	128

* Credit hours not specified.

principles should be employed in the design process. The fundamental elements often include setting objectives and criteria, synthesis, analysis, construction, testing, evaluation, and communication of results. Student problems should include some of the following features: creativity, open-ended problems, design methodology, formulation of problem statements, alternate solutions, feasibility, and design of system details in addition to economics. Drafting skill courses cannot be used to satisfy the design requirements. ABET states that normally at least one course must be primarily design at the senior level and draw upon material from other courses. This is often interpreted as the need for a "capstone" course, although ABET (1989) does not use this wording. Proposed changes in the accreditation criteria for design are discussed by Christian (1991). If approved, these changes will strengthen the requirement for a "meaningful, major engineering design experience," but the engineering science and design categories will be combined. This latter provision might reduce the amount of design at some schools, and the proposal is controversial.

Engineering courses do not need to be listed as entirely engineering science or engineering design but can be split between the two. When a program is accredited, the choice of split may have to be justified. Thus, a professor teaching an undergraduate course does not have complete freedom of content, but must take care to follow the split between engineering science and design that the department has designated.

The ABET accreditation procedure starts with a letter to the dean who responds that reaccreditation is desired. The school then fills out very detailed questionnaires for each program to be accredited. One volume of general information and a second volume with detailed information on each accredited engineering program are prepared. Resumes for all faculty members in the programs are included. An ABET team, which consists of the team captain and one member for each program to be accredited, visits the school for three days. The team members speak with faculty and students, study course notebooks prepared by the faculty, investigate student transcripts, tour the facilities, and ask for any information they consider to be pertinent. ABET examiners typically ask about class size, teaching loads, space availability, course work, and the quality and morale of faculty and students. A weakest-link theory is used to determine whether students have met the minimum ABET requirements. That is, it must be impossible for a student to graduate without satisfying the ABET requirements. Accreditation visits are considered extremely important, and considerable time is spent preparing for them.

The accrediting team has several choices of outcome in their report. They can accredit the program for a full six-year term or for an interim three-year period with a report to justify the additional three years. Or, the accreditation can be for three years with both a report and an additional visit required before the next three years will be accredited. For unsatisfactory programs a show cause might be given. A *show cause* means that the school must show why ABET should not remove accreditation. Finally, the visiting team may decide not to accredit the program. Note that an accreditation report that gives less than complete accreditation is often used to obtain needed additional resources from the university. In November 1992 the ABET Board of Directors approved the proposed changes in design criteria. The engineering science and engineering design critera in Table 4-2 are combined. The design experience must be developed and integrated throughout the curriculum and there must be a "meaningful, major engineering design experience."

4.7. CHAPTER COMMENTS

Writing objectives may be like many other things that are good for you but are not particularly pleasant. Prepare them once for one course. The experience will sharpen your teaching both in that course and in other courses, even if you do not formally write objectives for other courses. Bloom's taxonomy is extremely helpful in ensuring the proper distribution of class time, student effort, and quiz questions. Carefully classifying objectives and test questions as to the level on the taxonomy is also a very useful exercise to do for at least one class. Then in later classes the level will usually be obvious.

The ABET requirements may not be high on your list of interesting reading. However, if new faculty are unaware of the ABET requirements, it is unlikely that their courses will meet the spirit of these criteria. This is particularly true of including design as some fraction of a course. In addition, to be informed participants in the current debate on accreditation requirements, faculty must understand the current requirements.

4.8. SUMMARY AND OBJECTIVES

After reading this chapter, you should be able to:

• Write objectives at specified levels of both the cognitive and the affective taxonomies.
• Develop a teaching approach to satisfy a particular objective.
• Decide whether to use a textbook in a course and select an appropriate textbook.
• List and discuss the ABET requirements for accreditation of an undergraduate engineering program.

HOMEWORK

1 Pick a required undergraduate engineering course. Write six cognitive objectives for this course with one at each level of Bloom's taxonomy.
2 Write two objectives in the affective domain for the course selected in problem 1.
3 Pick an undergraduate laboratory course. Write two objectives in the psychomotor domain.
4 Objective 10 in Table 4-1 includes a cognitive and an affective domain objective. Classify each of these.
5 For the course selected in problem 1 decide whether a textbook should be used. Explain your answer.
6 The following statement can be debated. "ABET accreditation has strengthened engineering education in the United States."
  a Take the affirmative side and discuss this statement.
  b Take the negative side and discuss this statement.

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