CHAPTER 4

OBJECTIVES, TEXTBOOKS AND ACCREDITATION

What content to cover in a course is obviously a critical question for required courses that are prerequisites for other courses. 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, textbooks, and finally accreditation.

4.1. 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 requirements for accreditation of an undergraduate engineering program.

4.2. COURSE GOALS AND OBJECTIVES

Goals are the broad final results for a course. Usually they are stated in broad, general terms. 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.

Content comes first. Engineering education is centered on content, and goals and objectives should focus on it (Plants, 1972). General goals such as these are nonspecific and often fairly easy to agree upon. However, goals are not specific enough to be useful in an operational sense except as an overall guide for a course. 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 you know that you are not expected to cover statistical or irreversible thermodynamics, and professors of follow-up courses will know that students 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.

More specific *learning or behavioral objectives* are useful to guide both you and the students in exactly what they will learn, feel, and be able to do after each section of the course is completed (Besterfield-Sacre et al., 2000; Davis, 2009; Felder and Brent, 2003; Hanna and Cashin, 1987; Stice, 1976). A behavioral or learning objective states explicitly:

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

Writing a few learning objectives for a class forces you to think about observable behavior (how will you know the student has learned?), conditions, and level of performance. However, few engineering professors write out complete behavioral objectives for all their classes. Here is an example of a 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 one 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. Behavioral objectives are usually written in the form of the minimal essential objective and focus on relatively low-level skills since such skills are easiest to measure. For higher-level skills behavioral indicators of achievement without minimum standards are more appropriate (Hanna and Cashin, 1987). 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. Note that action verbs such as write, describe, solve, develop, determine, judge, evaluate, search, and select are used. Do NOT use verbs such as *know, learn* and *understand* because these verbs are not visible behavior (Felder and Brent, 1997). How would you know, for example, that a student "understands?" Felder and Brent (2003) give examples with emphasis on accreditation.

Objectives clarify the important content and ABET outcomes (discussed in Section 4.7) 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 (see Chapter 11).

Objectives should be shared so that students know what material to study and what material they will be tested on (Stice, 1976). Students should also be explicitly told if other skills, such as those involving a computer or communication, will be required. 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.

Note: ABET (Section 4.7) has invented their own nomenclature. What most of the educational world calls objectives, ABET calls outcomes. ABET reserved objectives for what graduates were expected to be able to do a few years after graduation.

4.3. TAXONOMIES OR DOMAINS OF KNOWLEDGE

Taxonomies of educational objectives were created by two 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. A problem-solving taxonomy has also been developed by Plants et al. (1980). These taxonomies are discussed in the following four sections. Bloom's taxonomy has been revisited by Anderson and Krathwohl (2001) and many commentators prefer this version.

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.
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 determine and describe second law fallacies in proposed power cycles.
7. The student can judge when classical thermodynamics is not the appropriate analysis tool.
8. The student can find and correct errors in his or her own solutions and in those of others.
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.

4.3.1. 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. 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. However, tests may contain too many knowledge level questions because 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 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 without using jargon. 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 questions) or oral exams. The second objective in Table 4-1 is an example of an objective at the comprehension level. A warning: engineering and science students can and often will skip the comprehension step and solve problems in the application and analysis steps (Mazur, 1997).
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, the cost of a particular type of equipment, the flow in a simple pipe, the deviation of a beam to a load, and the voltage drop in a simple circuit. Objective 3 in Table 4-1 is an example.
4. *Analysis.* Analysis usually consists of breaking down a complex problem into parts and determining the connections and interactions between the different parts. 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 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. Grading can be a challenge because 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 requires judging 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 that can be based on internal evidence but is easier to attain if external sources are also utilized. 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 optimal. Without getting into this argument, note that students need practice and feedback on all levels of the taxonomy to become proficient. Professors need 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.

4.3.2. Affective Domain

The affective domain 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 refers to inner growth as an individual adopts attitudes, principles, and codes to guide value judgments. The affective domain taxonomy has had considerably less influence in education than the cognitive domain taxonomy, particularly in engineering education. The five levels of the affective domain are (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 is it automatically rejected? 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 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, idea, 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 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 "the student will appreciate," which is at the level of valuing in the affective taxonomy, in objective 10 in Table 4-1. Unfortunately, measuring students' appreciation is difficult, and since "what gets measured is what gets improved" (National Academy Engineering, 2009) appreciation does not get improved.

4.3.3. 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, digital meters have replaced analog meters and calculators replaced slide rules. 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, keyboarding, 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 keyboarding. Because of the importance of computers and calculators in the practice of engineering, this psychomotor skill has become more important than in the past. Nonverbal communication needs to be congruent with the spoken message. Individuals can be successful engineers with speech handicaps. However, the ability to speak 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 10). Professors who desire to become outstanding lecturers need to develop their skills in speech behaviors (see Chapter 6).

4.3.4. Problem-Solving Taxonomy

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

1. *Routines.* Routines are operations or algorithms that can be done without making decisions. Many mathematical operations such as solution of a quadratic equation, evaluation of an integral, 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 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 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 (see Chapter 5) in that the new routine is not obvious from the known information.

4.4. THE INTERACTION OF TEACHING STYLES AND OBJECTIVES

To meet any of the objectives (including affective), students must have the opportunity to practice and receive feedback. If you want them to meet certain objectives, share these objectives with them and test for the objectives. Students will work to learn the stated objectives in the course. If objectives are not stated or are unclear, they will work to learn what they think you want. Remove the mystery and tell them what you want with 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 (with the exception of mastery learning) as long as students are given clear, definite objectives and a list of materials for attaining the objectives. This applies to the knowledge, comprehension, application, and perhaps analysis levels, but not to synthesis, evaluation or problem solving.

Engineering courses focus on cognitive content objectives. Knowledge-level objectives and content are the easiest to learn and can be learned from well-written articles, books, and class notes. If the objectives are clear, students will memorize the material. For example, if students reading this book are told to learn the six levels of the cognitive domain, they 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 is 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 discussion and/or questions so that students actively process the material. Discussion in groups can also be helpful for comprehension.

Applications in engineering usually mean 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 one 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 effective since the interactions help many students. Students who tutor and teach other students are highly likely to master application objectives since tutoring and teaching require one to structure the knowledge. Analysis objectives usually involve more complex, multi-step 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 first year engineering design courses. 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 that will do the routine calculations. The PMI approach (see Section 5.7.3) which finds pluses, minuses, and interesting aspects of the proposed solution is useful in encouraging students to be creative.

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. You can demonstrate the skill in class, by having the students practice evaluation, and providing feedback on their evaluations. One way to do this is to show an incorrect solution. After giving the students a few minutes to study the solution, you can grade the solution while the students watch. 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 to master objectives in the affective domain by sharing the explicit objectives with them in a positive fashion. For example, you 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 help students socialize and internalize the engineering discipline (this socialization is usually a major unstated affective objective), but they need to be related to the topic covered in class that day. 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 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 difficulties, engineering professors should know what resources are available for help.

4.5. DEVELOPING THE CONTENT OF THE COURSE

The content of each course is the topic of many faculty discussions. We do not intend to discuss disciplinary details. 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 study before graduation. This content must appear somewhere in the curriculum. Since required courses often serve as prerequisites for other courses, the prerequisite material must be covered. The only way to ensure that the expected content is covered is to communicate with other faculty. 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 the same as what the professor covered.) Discuss the outline with other faculty who have taught the course in the past or who might teach it in the future. Before making major course revisions or changing the textbook be sure that critical material is not deleted. Talk to engineers in industry to determine what they use. Unfortunately, some students will not use computers to solve problems unless required to do so. We believe that at least one course each year should require extensive computer calculation with spreadsheets, MATLAB, simulations, statistical packages, and so forth. The department faculty should decide what software will be used in a specified course.

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 coverage 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 and serial learners in the class (see Chapters 13 and 15). 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 visual material. Conscious use of a learning cycle (see Chapter 15) 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.

4.6. TEXTBOOKS

Textbooks (including electronic texts) are used in about 90% of college courses in the United States (Landrum et al., 2012). In the past many engineers kept their textbooks and used them as a primary reference for many years. Unfortunately, most students now sell their textbooks when the course is over. Useful discussions on textbook selection are included in Eble (1988), Lee et al. (2013), and Wankat (2002).

4.6.1. Should a Textbook Be Used?

A well-written textbook 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. However, a textbook usually provides only one viewpoint, may not include the content you want, may be out of date, may not be the ideal format for helping students learn to learn on their own, and the solution manuals for the problem sets may be readily available on the Internet.

Students in beginning courses rarely have the sophistication to wade through the research literature or to pick the gems from the dross of the Internet. Since basic knowledge is not changing rapidly, textbooks for beginning engineering courses do not become obsolete rapidly; and because of the numerous pressures to standardize lower division courses (e.g., transferring of credits, ABET requirements (Section 4.7), and movement of faculty between schools), textbooks which closely match the requirements of these courses are usually available. Thus, textbooks are usually used for required lower-division undergraduate courses. If an *appropriate* textbook is not available, a publish-on-demand textbook can be considered (see Section 4.6.3).

The situation is often different for undergraduate elective courses and courses at the graduate level. Since the market for specialized books is smaller than for required undergraduate courses, there will be fewer books to choose from and they will be expensive. Seniors and graduate students need less structure and can better cope with varying author styles and different nomenclatures. The original literature is more difficult to read since it was not written for students, but it is a good vehicle to help advanced students learn how to learn on their own. The original literature can often provide a sense of excitement missing from most textbooks. Thus, it may be appropriate to assign readings from the original literature.

Is the cost reasonable? Many engineering textbooks 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. However, assigning reading of E-journal articles that students access on their own is legal. "Fair use" allows use of copyrighted material in other reasonable educational activities. For example, showing copyrighted material during a lecture is allowed. See Section 3.3.7 for a more detailed discussion of fair use.

A good textbook can be a tremendous aid and save you a great deal of time if you use it. By developing the book for a course, the author has already done much of the organization and presentation of content for you. It is common for professors to assign reading an entire chapter and then skip a large portion. Students are adamant that they are busy and want to be told "exactly what to read" (Berry et al., 2011, p. 36). Although useful, books do limit what you can do in a class. Students won't mind if you occasionally require other readings. However, doing this extensively will annoy them and make them wonder why you have made them buy an expensive book and then never use it.

4.6.2. Textbook Selection

To some students the textbook is treated as if it contains **The Truth**. Perhaps this is a carryover from the monastic beginnings of universities where students studied "sacred texts" (Palmer, 1983). Because of this student devotion, 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. How does one choose an *appropriate* textbook?

Parts of the Book Used by Students. What parts of the book will the students actually use? In beginning courses students often want and need the assistance in solving problems that a textbook with good example problems provides. Sensing students particularly appreciate detailed examples. The students also appreciate the collection of physical properties and formulas provided in the textbook. If you assign homework problems from the book, the students will also use the homework sections. Students would benefit from careful reading of the text, but most students do not do this (Lee et al., 2013). Although course grades are positively correlated with the percentage of the reading completed (Landrum et al., 2012), 25–30% of the students do not read the textbook or class notes (Heywood, 2005; Berry et al., 2011).

Content Coverage. Does the content coverage match the coverage in the course? 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. Books that have light coverage of some topics may have to be supplemented 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. 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. Read a few chapters to make sure the ideas are current and accurate.

While looking at the content, check for typographical errors and fundamental mistakes. Not all books are created equal with respect to accuracy. A convenient way of comparing a number of books is to check a few key items that you will cover in your course.

Example Problems. Are the example problems high quality? Examples need to be more than a collection of equations with numbers plugged in. Examples need to explain how problems are solved. Use of a common problem solving strategy (see Section 5.4) is helpful because the students soon understand the basic pattern. Typographical errors 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.

Equations and Data. Are the necessary equations and physical constant data available and accurate? Equations and data need to be accurate with a limited number of typographical errors.

Cost. Cost is important to students and to the federal and many state governments (Berry et al., 2011). Although professors often ignore cost, they probably should include cost, and may be forced by state laws to include it, in their decision to adopt a textbook. Textbooks that are free on the Internet are very popular with students, and certainly should be considered if their coverage is close to course requirements.

Homework Problems. Homework problems should be clear and unambiguous. It is also helpful if the level of difficulty of the problems is indicated. Examine the solutions manual since it is 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 developing the homework problems. However, since most solution manuals are available online, professors will need to write some homework assignments.

Learning Friendly. Although you can assume that most authors of engineering textbooks understand the content, you cannot assume that they understand how students learn. Introductory textbooks should use an inductive approach starting with specifics and leading to generalities (See Section 15.3.1), and should be written in a concrete instead of an abstract style. 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. 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.

Student Friendly. Is the book's organization student friendly? Robinson (1994), who assumed that students will read the textbook, states a student-friendly book will contain:

- *Objectives*
- *Questions* for the student
- *Transitions* between topic that show the relationships among the topics
- *Signals* (e.g., italics) that indicate the material is important.
- *Advance organizers* (e.g., an outline or flow sheet) to help provide the global picture.

E-books. The availability of an e-book is coupled with the cost criterion. According to the *Chronicle of Higher Education Almanac* (2013) over 89% of all students were satisfied or very satisfied with use of an e-book in a core course. Students who preferred an e-book listed the following items: easy search and reference, easy to carry around, costs less, available quicker, convenient, and interaction with content. Engineering students have different needs and may be less satisfied with e-books. Table 8-1 shows students' preferences for more e-book use.

Supplemental Material. Is there supplemental material that will be used? If you will be teaching a course that is not your major interest, a solutions manual that correctly solves problems will be helpful even if the students obtain solution manuals from the Internet. 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 advantageous if the software is compatible with the school's computer system, but software increases the price of the book. Some engineering textbooks integrate software into the homework assignments and the teaching of the content. Some textbook's websites have additional useful material such as slides.

Permanence. 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 in the hard copy of a book it is essential for reference use (electronic copies can use the search engine available in the file format). 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. Note that e-books are usually active for only a relatively short period, so they and rentals will probably not be available for reuse. A laboratory workbook that will probably be discarded does not need this kind of quality.

Once the data has been gathered, how do you make the decision? Although a number of good decision making methods have been developed, our favorite is the Kepner-Tregoe (K-T) Decision Analysis (Fogler et al., 2013). To apply the K-T method to textbook selection one would

Table 4-2. Sample K-T Decision Analysis for Textbook Selection

MUST HAVE	Text 1	Text 2	Text 3
Appropriate coverage	Go	Go	Go
Example problems	Go	Go	Go
Solution manual	Go	Go	No Go
Electronic version	Go	Go	Go

WANTS		Text 1		Text 2		Text 3
	Weight	Rating	Score	Rating	Score	
Topic 1	6	8	48	7	42	**NO**
Topic 2	5	4	20	7	35	**GO**
Topic 3	2	10	20	2	4	
Quality soln manual	7	6	42	3	21	
Learning styles	6	4	24	4	24	
Cost	5	1	5	8	40	
Total			159		166	

first list the content areas and features (e.g., cost, examples, quality of hard copy, electronic copy available, and solution manual) that are useful in the course. These features are then classified as either *must have* or *wants.* The must have items are either present, Go, or not present, No Go. The want items are rated for each textbook and values are listed in a K-T table (see Table 4-2). Although not necessary, it is often useful to assign weights to each want item. Note in Table 4-2 that appropriate coverage and availability of a solution manual are must have items *and* the quality of the topic presentations and of the manual are ranked under wants (double ranking is not part of the original K-T method, but was added since it makes sense for this example). Accommodation of learning styles is discussed in Section 15.3.3. Cost is ranked inversely with lower cost books receiving a higher ranking. In this example, Text 3 is a No Go because there is no solution manual, and the cost rankings are the deciding factor in choosing Text 2.

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.

4.6.3. Print-on-Demand and Publish-on-Demand Textbooks

Print-on-demand is currently common for books not expected to have large print runs. The text, tables and figures for the book are stored in an electronic file. After an order is registered, the electronic file is read to a rapid printer that prints the entire volume, which is then bound and sent to the purchaser. This publishing model reduces the expensive inventory of unsold books to essentially zero. Some publish-on-demand organizations, such as Lulu.com, allow self-publishing while others such as Springer use publish-on-demand mainly for out of print books. In addition to printing hard copies publishers often offer downloading of files from the web, which with some publishers is free.

The publish-on-demand textbook is an alternative for professors who want to customize the textbook so that students do not buy chapters they will not use. A large number of books and other resources are stored as electronic files. The user selects the parts wanted 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 in the desired order, and the books are bound and shipped to the school. The cost is proportional to the book size.

With publish-on-demand technology, chapters from different books and even chapters written by the professor can be included in the made-to-order book. The publisher (e.g., http://www.academicpub.com/) takes care of obtaining permissions and paying appropriate royalties and fees. 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 are much less transferable from school to school. Thus, the publisher will probably sell more new copies.

However, this is still a relatively 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 is still under development. Of course, there's no guarantee that a single author will be consistent in the use of nomenclature either. Content is available from a large number of publishers, but content from the largest publishers such as McGraw-Hill, Pearson, and Wiley may not be available except from that publisher. Acceptance by the professoriate and by students is also not assured.

4.6.4. 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). The motivation to write a textbook in engineering often arises from dissatisfaction with the available textbooks or the total unavailability of any textbook in a new field. Writing a textbook is difficult but rewarding. While writing the textbook, the professor is likely to be vitally interested in the class and will probably do a good job teaching the course. 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. However, since 80% of the sales are from 20% of the books, many books make very little money (Burroughs, 1995).

The common wisdom is that engineering professors should wait to write a textbook until they have tenure. 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 5.3). Because of the period of time required, writing one is risky for an assistant professor. And, most importantly, since many promotion and tenure committees and many administrators at research universities do not look favorably on textbooks, they may not help an assistant professor be promoted (Burroughs, 1995).

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 for writing engineering textbooks (Beakley, 1988; Bird, 1983) and for writing general books (Lepionka, 2008; Wankat, 2002; Zerubavel, 1999). Lepionka (2008) discusses the pedagogical elements that will help students learn from your textbook. If you are thinking that you will have your lecture notes transcribed and that will give you a book, read Lepionka's (2008, p. 171) argument why converting lectures into books rarely works. I (PCW) tried starting with my lecture notes as a first draft for one chapter of my junior chemical engineering textbook, and then spent more time revising that chapter than any other.

New textbook authors should seriously consider joining the Text and Academic Author's Association (TAA, http://taaonline.net) and benefit from news and author assistance. Joining TAA is particularly helpful for learning about contracts and what publishers do, but, of course, it is not helpful for deciding upon appropriate content. A little knowledge (such as that a 15% royalty on a publisher's net receipts is common for college textbooks) is very helpful when a contract is negotiated. However, our advice to potential authors is simple. Do not write a book for the money—you can make more money consulting. The textbook market is in turmoil and companies are not confident that their business models are sustainable (Boroughs, 2010). The golden age (1960s to 1980s) of textbook writing, when engineering authors could confidently order a new Porsche if their book did well in securing adoptions, is over. However, if writing a book is the right thing to do for other reasons, do it. Signs that it is the right thing to do include:

- You've taught the course for several years, and the available books are not satisfactory.
- You *know* you can write a better book.

- You feel *compelled* to write a book.
- You have already written extensive supplemental handouts for the class.
- 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 for another big project.

With appropriate changes in wording, the same signs apply to developing computer-aided instruction (Section 8.7), or an educational computer game (Section 8.5).

4.7. ACCREDITATION OF UNDERGRADUATE PROGRAMS

Author's Note. This section has been completely rewritten to match the current Engineering Accreditation Commission (EAC) of ABET (formerly the Accreditation Board for Engineering and Technology) accreditation policy EAC-2000. Since most engineering professors just refer to ABET and ABET-2000, we will do the same.

Most engineering programs in the United States are accredited by ABET. Accreditation 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.

4.7.1. The Accreditation Cycle

Universities request and pay for the costs of ABET accreditation. The ABET accreditation procedure starts with a letter to the dean who responds that reaccreditation is desired. The institution then develops very detailed self-studies for each program to be accredited. Both general information about the institution and detailed information on each accredited engineering program are prepared. The program self-study explains the program and details how the program meets the ABET criteria that are delineated below. Resumes for all faculty members in the programs and a syllabus for every course in the curriculum are included.

In the normal schedule the self-study is due in July, and a fall program visit is scheduled. A program must have at least one graduate before ABET will schedule a visit. Before the ABET visit each program sends ABET transcripts for recent graduates—ABET specifies how they are to be collected (e.g., ABET may ask for transcripts of the first six graduates with a last name beginning with K).

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; interview selected professors, staff, students and administrators; and obtain answers to questions raised while reading the self-study. Accreditation visits are considered extremely important, and considerable time is spent preparing for them. The ultimate question the evaluator has to answer is, does the program satisfy the ABET criteria (Section 4.7.2)?

Accrediting teams write their report before leaving the campus. Many teams work with the institution to solve difficulties before they write their report. The accrediting team has several choices of outcome in their report. They can accredit the program for a full six-year term either with no difficulties or with a *concern* (this is a flag for the next visiting team to look at this issue). If there is a *weakness* (one or more criteria were not satisfied) accreditation can be for an interim three-year period with a report to justify three additional years, or 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. Accreditation reports that give less than complete accreditation are often used to obtain needed additional resources from the university.

After the visit is over, the accreditation cycle is not finished. Institutions first have a week to correct errors in fact. After they receive the ABET draft report, they have 30 days to respond to any problems that were observed. Usually, the best response is to fix the problem. Based on this additional information, the original visiting team's report, and a comparison with other schools being evaluated, ABET makes a final decision that is conveyed to the institution in the summer. Since ours is a litigious society, negative ABET reports are often contested further.

4.7.2. ABET Criteria

The ABET criteria are laid out in an ABET publication (ABET, 2013) available free on their website, http://www.abet.org. The eight general criteria that apply to all engineering programs are outlined in Table 4-3. There are also program-specific criteria that apply to programs such

Table 4-3. Summary of ABET Criteria for Accreditation of Engineering Programs

Criterion 1. Students	Evaluate performance, monitor performance, and enforce policies.
Criterion 2. Program Objectives	Expectations for students a few years after graduation.
Criterion 3. Student Outcomes	What students will know and be able to do at graduation. See Table 4-4.
Criterion 4. Continuous Improvement	Process to assess and evaluate meeting outcomes, and to use results as input to improve.
Criterion 5. Curriculum	Subject areas appropriate for engineering. See Table 4-5.
Criterion 6. Faculty	Sufficient number and quality to properly run program.
Criterion 7. Facilities	Classrooms, offices, labs, library, and computer services support learning activities.
Criterion 8. Institutional Support	Support and leadership ensure program quality and continuity.

as mechanical or biomedical engineering. Criterion 1 refers to the program's policies with respect to students. The ABET evaluator tries to determine if the policies are applied fairly and uniformly. Each program must consult with its constituencies and determine appropriate program objectives (criterion 2). The objectives indicate what successful graduates will attain a few years after graduation.

For graduates to meet the objectives, a series of learning outcomes are specified in criterion 3. The eleven outcomes specified by ABET are given in Table 4-4. Five of the criteria refer to technical outcomes (criteria 3a, b, c, e, and k) and six refer to professional outcomes (criteria 3d, f, g, h, i, and j). One of the complaints about ABET-2000 is that there are too many outcomes and ABET gives no formal guidance as to which outcomes are more important. There is widespread support for professional criteria 3d (teams) and 3g (communication). In their brilliant Chapter 16 (a must read for all professors) Sheppard et al. (2009) describe the need to instill core ethical and professional values (3f) in students—and this includes the need for ethical behavior—a topic curiously missing from criterion 3f. However, since Loui (2005, p. 388) found that "a course in engineering ethics reinforces the students' previous inclinations to act morally," there probably is an effect on behavior. Criterion 3i is widely believed to be important, but how to assess "a recognition" is not clear. The importance of learning after graduation is reinforced by studies of graduates that show they need several years of on the job education before they are ready to engineer (Williams et al., 2014). Professional criteria 3h and 3j are considered by practicing engineers one to ten years after graduation to be less important (Passow, 2012) and have significantly less faculty support than the other criteria (Lattuca et al., 2006). Unfortunately, disconnects over globalization issues exist between new engineers and most professors and many experienced commentators who consider criterion 3h to be critically important (National Academy of Engineering, 2005; Williams et al., 2014). Some ABET program evaluators privately state that as long as a program does anything to teach and assess criteria 3h, 3i and 3j, they accept it.

Table 4-4. ABET Student Outcomes (Criterion 3)

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice."
(l, m,) any additional outcomes added by the program.

In the early years of ABET-2000, program examiners were most interested in the methods used to assess the outcomes. ABET requires direct assessment of how much the students have learned either by the professor, by a visiting committee, or with a national examination such as the Fundamentals of Engineering examination. ABET allows direct assessment data to be supplemented with indirect assessments such as student interviews or surveys about the quality of their education. Initially, most engineering professors strongly resisted assessment because they thought it would be too time-consuming and they were not used to being told what to do.

After realizing that direct instructor assessment of student outcomes can require little additional time for the technical criteria, many professors acquiesced (Briedis, 2008). The trick for easy direct assessment of technical outcomes is to first define the course outcomes (Besterfield-Sacre, 2000; Felder and Brent, 2003), and then write questions or problems that assess one outcome at a time. The scores on this question are mapped to the assessment levels being used. The nationally normed Fundamentals of Engineering examination, the first step to becoming a professional engineer, provides excellent averaged direct assessment data for analyzing satisfaction of outcomes 3a, 3e, and, to a lesser extent, 3f.

Teaching and assessing the professional criteria remain hurdles for most engineering faculty. A number of direct assessments were initially developed, but the most powerful were also the most time consuming (Shuman et al., 2005). As a result many of the more detailed assessment procedures such as student portfolios, behavioral observations, and performance appraisals are seldom used on a large scale. *Rubrics* (detailed descriptions of what students at different levels of accomplishment can do) are commonly used by instructors for direct assessment of the professional criteria. Rubrics have the advantage that their use makes grading more detailed and fairer but does not significantly increase grading time. Use of a rubric forces the professor to look at the important components of the assignment. Sample rubrics are available in the literature (Rogers, 2010; Stevens and Levi, 2012; Walvoord and Johnson, 2010) and in this chapter's appendix.

Students often learn many of the skills necessary to satisfy the professional outcomes outside of class in internships, clubs, work, and research. Hirsch et al. (2005) studied students who were part of a summer research experience for bioengineers. The students made measureable improvements in satisfying ABET outcomes 3f and 3g without taking formal courses.

Recently, ABET examiners have been paying most attention to criterion 4, continuous improvement. Does the program regularly assess the student outcomes, evaluate the extent that targets are being met, and systematically use the evaluation results to improve the program? The key appears to be to have a plan that regularly, at least once per year, reports on the evaluation results to a committee or the department head, and then plans for improvement based on the data that are formulated and followed.

Table 4-5. Summary of ABET Criterion 5, Curriculum

Mathematics and Basic Science (biological, chemical, and physical, including some experimental) appropriate to discipline	1 year
Engineering sciences and design (curriculum must culminate in a major design experience—see Section 9.1) appropriate for the discipline	1.5 yrs
General education to complement the technical content	*
Base	4 years

* Amount not specified, but students need to meet the outcomes in Table 4-4.

Previously the curriculum was fairly constrained, but the current requirements (criterion 5) are quite general (Table 4-5). These are minimum requirements, and individual engineering disciplines may impose additional requirements. Previously, mathematical studies had to include differential and integral calculus and differential equations. This has been changed to be "appropriate to the discipline," leaving considerable latitude to the program. At the same time the program has to be ready to show that the mathematics and sciences are appropriate. In the past, programs often included computer science with the basic sciences, but this is no longer acceptable. The engineering sciences include mechanics, thermodynamics, electrical circuits, materials science, fluids, heat transfer fundamentals and so forth. Engineering design used to be a controversial area, but proving the students have had a major design experience is now simpler. The general education component includes both elective and required courses in humanities and social sciences. The laboratory experience should include design of experiments and interpretation of data (criterion 3b). The computer-based experience should be sufficient enough so that the student can demonstrate efficiency in application and use of digital computers (criterion 3k). Competency in written and oral communication (criterion 3g) is expected.

Criterion 6 considers only the faculty who are actually involved in the program. Those who are in the department but not involved with the program are not considered. Criteria 7 and 8 are typically not problems for institutions that do not have major budget difficulties. There can be a concern about leadership if no one is clearly in charge of the program. In addition to these general criteria, many programs have to satisfy program specific criteria. For example, computer engineering programs must include discrete mathematics.

4.7.3. The Impact of ABET-2000 on Engineering Education

The authors agree with Latuca et al. (2006) that the changes made in ABET-2000 have had a positive role in engineering education. The outcomes-based assessment used in ABET-2000 is more flexible than the former method. This has allowed one of the authors to accredit a multidisciplinary engineering program that would not have been accredited under the old rules (Wankat and Haghighi, 2009; see Section 4.8). Accreditation of novel programs is possible, but requires extra attention to assessment, evaluation of assessment, and continuous improvement.

Looking at individual outcome criteria and obtaining regular feedback from graduates and employers makes it much easier to spot deficiencies in the curriculum. Explicit requirements to teach and assess the professional criteria have improved graduates' skills (Latuca et al., 2006) and will help prepare graduates for jobs in the service sector (Wei, 2008). Writing and disseminating course objectives, which are required by ABET-2000, improves courses (Besterfield-Sacre et al., 2000).

We believe the main reason most engineering professors were initially against the ABET-2000 changes, and many are still against assessment and data-based decision making (Latuca et al., 2006), is that assessment partially focuses on the teaching effectiveness of faculty. Many professors resist evaluation of their teaching performance. Teaching methods appear to be more difficult to change than content.

We believe there are the following problems with the functioning of ABET:

1. ABET has not clarified the balance between minimum standards, continuous improvement, and the value of assessment (ABET, 2004). A program with highly accomplished students and graduates, but relatively weak documentation of assessment or of continuous improvement, will probably have more difficulty with accreditation than a program with much less accomplished students and graduates but with strong documentation of the assessment and continuous improvement systems. National norming (e.g., the Fundamentals of Engineering exam) would allow examiners to compare students' levels of learning.
2. Eleven criteria for learning outcomes are too many, and they should be streamlined. One option would be to have three, more general, criteria: engineering science, engineering design, and professional skills.
3. ABET's rules are not transparent. For example, ABET program evaluators will privately state that as long as a program does anything to teach and assess criteria 3h, 3i, and 3j, they accept it. If that is true, EAC should clearly state this in its written documentation.
4. The amount of documentation required is onerous. Page limits on each section would aid both programs and program evaluators.
5. ABET has realized for quite some time it needs to develop methods to ensure uniformity among program evaluators (ABET, 2004).
6. ABET needs to heed the methods used by Lattuca et al.'s (2006) major analysis of the effectiveness of ABET-2000. Their study relied on surveys and self-reports, which they carefully benchmarked as providing meaningful information. Ironically, engineering programs cannot use surveys and self-reports as their only assessments (Briedis, 2008).

4.8. CURRICULUM DEVELOPMENT CASE STUDY

The use of case studies in engineering education is discussed in Section 9.2.5. This case study can either be read through in the same way as the remainder of the text—as information—or it can be done as an interrupted case study by determining what you would do at each new subsection.

4.8.1. Background Information

In 1969 Purdue University developed an Interdisciplinary Engineering Studies (IDES) program that was purposely not ABET accredited so as to have maximum flexibility. In 2000 one of the authors (PCW) became the half-time program director. Since the students took their engineering courses from the other engineering programs, the director was the only faculty member paid by the program. The IDES program required 124 semester credits to graduate , which could be satisfied in eight semesters of full-time attendance taking a normal load of five or six courses for 15 to 16 credits each semester. The students took the same first year program as other engineering students (calculus I and II, chemistry I and II with lab, physics I with lab, English, speech, and introduction to engineering and computers). After completing the first year, students selected their engineering major, and, if they became IDES students, they also selected a concentration in IDES. In the sophomore year IDES majors took the same multi-variable calculus, differential equations, and physics II (electricity and magnetism) classes as other engineering students. The IDES students also took the same 18 credits of general education as other engineering students.

However, the IDES program differed by not having a required engineering core and requiring only 30 credits of engineering versus a minimum of 47 credits for an ABET accredited program. The difference of 17 credits was added to other electives to form the "area." Area electives (totaling about 30 credits) allowed students to take almost any course in the university to develop unique concentrations that were not possible in a standard engineering program. Examples included engineering management, acoustical engineering, and a student-designed option. Because of its flexibility, the IDES program was expected to serve as an incubator for development of new programs such as biomedical engineering.

Earlier policy had been to allow students to take courses that "were in the student's and Purdue's best interests." As a result rules were lax and some students found a relatively easy path to an engineering degree. The IDES program also had the largest percentage of students who entered the program by internal transfer—usually from another engineering program. IDES had thus become a haven for students who found other engineering programs either too difficult or distasteful. The requirements were tightened mainly by enforcing existing rules.

Many engineering professors felt that IDES students were well below average and were a burden to teach. In reality, because IDES also had a pre-medical engineering program and some students went well beyond the minimum requirements, the GPAs of students in IDES were bimodal. These professors also felt that they did not receive any recognition or benefits from teaching IDES students. Because IDES students were placed in existing classes when there was room available, the program was the least expensive per graduate in the university. The dean of engineering realized that the program served a purpose, but did not want the problems that would occur if the program grew. Thus, enrollment was limited to a total of 100 students, which kept complaints to a minimum.

Every year the director received letters from graduates who were not able to become Professional Engineers because of the lack of ABET accreditation. In the past, accreditation was not possible because ABET required a minimum of three professors in a program and a program that did not teach any of its engineering core would have been unacceptable. With the increased flexibility of ABET-2000 it might be possible to have an accredited program with the desired flexibility, but more faculty involvement would be required. Obtaining money and space for additional faculty was not fiscally or politically possible.

In 2003 a new dean of engineering constituted an ad hoc committee to consider changing the Department of Freshman Engineering (FrE) from a non-degree granting service department into a Department of Engineering Education (ENE). In addition to being in charge of the first year program, ENE would do research in engineering education and offer PhD and MS degrees. The Head of FrE was totally in favor of this change, and he had only accepted the appointment as the Head of FrE with the understanding that the department's role would be changed significantly. The IDES director, who was also interim associate dean of engineering for education, served on the committee. In an interesting intertwining of roles, the head of FrE and the director of IDES both reported to the associate dean.

After a few meetings of the ad hoc committee, the associate dean realized that the proposal for ENE would produce an incomplete department since there would be no undergraduate degree program. In his role as director of IDES the associate dean realized that the formation of ENE was an opportunity to obtain faculty dedicated to the IDES program, which would allow development of a program that met ABET accreditation requirements. However, IDES would have to relinquish its independence and become part of ENE. Independent control of budget and of space was the major advantage that would be lost.

Would you work to make IDES a part of ENE? Why or why not?

If you decided to work to make IDES a part of ENE, how would you go about doing this? What could go wrong?

4.8.2. Decision and Action Steps

After weeks of privately mulling over the possible ramifications of merging FrE and IDES, the IDES director decided that a merger would be in the best interests of Purdue and of the students. Not only would the merger give ENE an undergraduate program and allow IDES to pursue ABET accreditation, it would also make ENE stronger by providing extra space and budget.

What was the best way to accomplish a merger? Ordering the merger as associate dean or asking the dean to order the merger would undoubtedly cause faculty resistance. To avoid the development of unnecessary resistance, the associate dean requested that the dean change the charge to the committee to include the possibility of ENE developing an undergraduate program. Once the merger was explained to her, the dean agreed.

After the announcement of the change in charge to the committee, one unforeseen difficulty occurred. The Head of FrE demurred because he was afraid that he would be shunted aside. After he was reassured that the proposed merger was not a coup and he would remain as Head of ENE, he became an enthusiastic supporter.

In April 2004 FrE and IDES were merged to form ENE. The first order of business involved developing MS and PhD programs in engineering education. Once that task was well under way, early in 2005 the director of IDES, now a part of ENE, started planning for an ABET accredited program.

How does one plan a new ABET accredited engineering program?

Considering the background information, what constraints need to be included in the program design?

Which ABET program area would you seek to be accredited under? (Check out the ABET web site for the options.)

If the total credits to graduation are not changed, how many engineering credits would be required and what would the engineering core look like?

4.8.3. Design of the Curriculum

The new program had to fit within the context of engineering at Purdue, it had to satisfy ABET requirements, and it had to satisfy the major reason for seeking ABET accreditation, which was the thwarted desire of graduates to become professional engineers.

In the context of the engineering college the program would have to pass scrutiny of the Engineering Curriculum Committee (ECC) and of the Engineering Leadership Team, which consists of deans and heads. The program would have to follow the college rules: use the common first year program and follow the college's general education program. Since many engineering disciplines were already accredited at Purdue and since the program would be multidisciplinary, the decision was made to have the program be as flexible as possible subject to the constraints. We decided to seek ABET accreditation in the Engineering, Engineering Physics, and Engineering Science program area. None of the existing Purdue programs were accredited by this program area, and since there are no program criteria, the program would have maximum flexibility. Newberry and Farison (2003) classified the three types of general engineering programs accredited by ABET as philosophical, instrumental (planning to convert to disciplinary programs) and flexible. Purdue's program would fit with the ten flexible programs accredited in 2003. A timing constraint was that Purdue's next ABET visit would be in fall of 2007. To be accredited during this visit, the program needed a May 2007 graduate. The only way to have a graduate in two years was to have a transfer student be the first graduate.

Next, the constraints on the program were delineated. Total credits would be 124, the same as the existing IDES program. Since ABET accreditation was a major goal, the ABET requirements in Table 4-5 would have to be satisfied with at least 47 credits of engineering and 31 credits of mathematics and basic science. Purdue requirements of a common first year engineering program (8 credits math, 8 credits chemistry with lab, 4 credits physics with lab, 4 credits introduction to engineering including computer software, 4 credits of English and 3 credits of speech); common sophomore mathematics through differential equations (8 credits); and a common engineering college requirement of 18 additional credits of humanities and social science would be adhered to. Decisions were made to change the sophomore physics requirement to 3 credits of basic science and to make the engineering requirement 47 credits at the sophomore year and above (51 credits engineering total) to provide a cushion for experimentation.

The content of the engineering courses was constrained by the necessity of satisfying ABET criteria in Tables 4-3 and 4-4, and the desire to have students pass the Fundamentals of Engineering (FE) exam. The general part of the FE exam consists of questions in mathematics, probability and statistics, chemistry, computers, ethics and professionalism, engineering economics, statics, dynamics, strength of materials, material properties, fluids, electricity & magnetism, and thermodynamics. The math, chemistry and computers are covered in their first year and sophomore core courses. We decided to cover ethics and professionalism in a one-credit professional seminar that is part of the engineering core. The other courses in the engineering core are circuits, thermo, statics, dynamics, engineering economics, fluids, and a major design experience course. Total in the core is 19–22 credits depending on which statics-dynamics sequence is chosen. A 3-credit statistics selective is also required—most students take engineering statistics (a selective is a course chosen from a short list of alternatives).

The core is unique in that to maximize flexibility we follow the procedure used by the FE exam: instead of specifying courses we specify topics. For example, we accept any of the four beginning engineering thermo courses taught at Purdue. We initially had 5 credits of engineering selectives including 2 credits of hands-on lab and 3 credits of design. However, in the ECC the representative from Materials Engineering pushed very strongly to require a course in materials. After some negotiation, the ECC agreed on adding a 3 credit selective in either materials or strength of materials. Including this selective, students will have covered 93% of the topics on the FE exam. The remaining credits of engineering (usually 14) are used for depth in the students' concentration (e.g., acoustical engineering). Students also had 17 credits of free electives that were used to meet requirements of the students' concentrations. For example, students in engineering management take management courses and students in visual design engineering take computer graphics technology and art and design courses. Wankat and Haghighi (2009) discuss the program concentrations in detail.

A major challenge was to ensure that students satisfied ABET criteria 3 a–k (Table 4-4). Since all of the engineering courses are taught by ABET accredited programs, we could identify courses where technical criteria 3a, b, c, e, and k were taught and assessed. For example, criteria 3a and 3e are taught and assessed in statics regardless of which department teaches the course. All of the engineering programs also teach and assess the professional criteria, but they often do this assessment in courses that are seldom taken by students in the new program. The strategy for the professional outcomes 3d, 3f–3j, and 3l (an outcome on leadership added by the program) was to teach these outcomes and assess extensively in the professional seminar and in the major design experience courses. Since the students' concentrations can be quite different, we allowed students the option of taking either EPICS (Purdue's engineering service learning course, see Section 7.10) or a major design experience course offered by ENE faculty. Both of these options would do extensive assessment.

Flexible general engineering programs generally combine courses from the engineering disciplinary programs (Newberry and Farison, 2003). Because students took most of their core courses from the disciplinary engineering programs, the faculty of ENE originally taught only 4 credits: the 1-credit professional seminar and the 3-credit major design experience course. Because students in the new program take seats in courses that would otherwise be vacant, the program continues to be inexpensive for Purdue. The professional seminar was first offered in spring 2006 and every spring since then. Because ENE was in the process of hiring new professors, the ENE major design experience course could not be developed and offered until spring of 2008, which was after the ABET visit. The first graduate used EPICS to satisfy this requirement.

Since the program originally controlled less than 10% of the engineering credit taken by the students, what can the program do to show that the ABET criteria, particularly criteria 3 (Table 4-4), are satisfied?

What steps would you take to prepare for the ABET visit?

4.8.4. Visit Preparation

Every student was assessed in the professional seminar and the capstone design courses—sampling was not used in these courses. The assessment program included direct assessment of all criteria 3 outcomes, except for 3b (experiments), in the courses taught by ENE faculty. Indirect assessments by surveys and interviews of all criteria 3 outcomes were done in the professional seminar, and all graduating seniors were interviewed.

FE exam results were used for outcomes 3a and 3e. Although the FE exam is taken by volunteers, the majority of program graduates take the FE because it is highly recommended and the program reimburses students who pass the cost of the exam. Our data (collected after the first visit) shows no significant difference in the GPA of those who took the FE and who did not (passing rates do correlate with GPA). In addition, the program received sampled assessment data for most of the other core courses on what was supposed to be a three-year rotation, but ended up being somewhat erratic.

Starting a year early, the ABET self-study was prepared. Because of the novel features and complexity of the program, this document was considerably longer than most self-studies.

The final document was about 100 text pages and 200 pages of appendices. Although the document was started well in advance, it could not be finished until after assessment data from the spring semester was available in June.

Shortly before the first official graduate was scheduled to graduate in May 2007, the program director discovered that ABET does not allow accredited programs to have the same title as unaccredited programs. Thus, a new name had to be found quickly. All involved parties (the ENE faculty, the first graduate, the Industrial Advisory Council, Dean of Engineering, and the Registrar) agreed to the name Multidisciplinary Engineering (MDE) for the ABET accredited program. IDES was retained as a small unaccredited program.

Since Purdue has a number of professors who are ABET visitors, we asked many questions. However, there was a limit to the amount of time we thought we could ask volunteers to donate. We hired a consultant, a retired professor who had done a large number of ABET visits, to conduct a mock visit. This visit was extremely helpful and a bit humbling since we had overlooked a number of important items.

The MDE program's first official student to graduate was in May 2007 and the first ABET visit was scheduled for October of 2007. Notebooks including a syllabus, handouts, and examples of student work were assembled for the most commonly taken core courses. A major advantage of doing the MDE accreditation at the same time as the other engineering programs at Purdue was that engineering professors had to assemble notebooks for their program's accreditation. Thus, obtaining a copy for the MDE visit required very little extra work.

4.8.5. Final Results

The accreditation was successful and the program was accredited in summer 2008.

Between visits a number of improvements were made. Several graduates commented that a CAD course would have been very helpful. After discussions with the Industrial Advisory Council, a CAD course became a program requirement. As a second example, after the first ABET visit we noticed in exit interviews that students seldom mentioned any computer work during their sophomore and junior years. To increase the opportunity for students to satisfy criterion 3k and to increase the networking opportunities of MDE students, the MDE program started teaching our own engineering statistics course in the junior year. In addition, graduates were surveyed to check for satisfaction of objectives. Half of the graduates contacted responded. Most had already satisfied the program objectives or were well on their way to satisfying the objectives.

The second ABET visit was in October 2013. The program was fully accredited for a second time in summer 2014.

The take-home lesson here is that if you want to accredit a novel engineering program, you need to do extensive assessments of every student and then use the results to improve the program. This formula is simple, but faculty has to buy in to assessment to make it work. In addition, hiring a consultant to do a mock visit will be money well spent.

4.9. CHAPTER COMMENTS

Write detailed behavioral objectives 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 one's 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 professional criteria 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.

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.

REFERENCES

ABET Engineering Accreditation Commission. (2013, Oct.). *Criteria for accrediting engineering programs: Effective for reviews during the 2014–2015 accreditation cycle.* Baltimore, MD: ABET. Retrieved from http://www/abet.org/eac-criteria-2014-2015/

ABET. (2004). *Sustaining the change.* Baltimore, MD: ABET. Retrieved from http://www.abet.org/sustainingchange/

Anderson, L. W., & Krathwohl, D. R., eds. (2001). *A taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of Educational Objectives* (Complete Edition). New York: Longman.

Beakley, G. C. (1988). Publishing a textbook? A how-to-do-it kit of ideas. *Engineering Education, 78*(5), 299–302.

Berry, T., Cook, L., Hill, N., & Stevens, K. (2011). An exploratory analysis of textbook usage and study habits: Misperceptions and barriers to success. *College Teaching, 59*(1), 31–39. http://dx.doi.org/10.1080/87567555.2010.509376

Besterfield-Sacre, M.,Shuman, L. J., Wolfe, H., Atman, C. J., McGourty, J., Miller, R. L., . . . Rogers, G. M. (2000). Defining the outcomes: A framework for EC-2000. *IEEE Transactions on Education, 43*(2), 100–110. http://dx.doi.org/10.1109/13.848060

Bird, R. B. (1983). Book writing and chemical engineering education: Rites, rewards and responsibilities. *Chemical Engineering Education, 17*(4), 184–193.

Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational objectives. Handbook I: Cognitive domain*, New York: David McKay. (This book has many examples from a variety of areas.)

Boroughs, D. (2010). 'Bye the book. *ASEE PRISM, 19*(8), 28.

Briedis, D. (2008). Embedded assessment: Easing the faculty workload. In W. E. Kelly, ed., *Assessment in engineering programs: Evolving best practices* (pp. 143–157). Tallahassee, LF: Association for Institutional Research.

Burroughs, R. (1995). A Textbook Story. *ASEE PRISM, 4*(6), 28.

Chronicle of Higher Education, The. (2013). College students' attitudes about e-textbooks, 2011–2012. *Almanac of Higher Education 2013*. Retrieved from http://chronicle.com/article/College-Students-Attitudes/140759/

Davis, B. G. (2009). *Tools for teaching* (2nd ed.). San Francisco, CA: Jossey-Bass.

Eble, K. E. (1988). *The craft of teaching* (2nd ed.). San Francisco, CA: Jossey-Bass.

Felder, R. M., & Brent, R. (1997). Random thoughts: Objectively speaking. *Chemical Engineering Education, 31*(3), 178–179.

Felder, R. M., & Brent, R. (2003). Designing and teaching courses to satisfy the ABET Engineering Criteria. *Journal of Engineering Education, 92*(1), 7–25. http://dx.doi.org/10.1002/j.2168-9830.2003.tb00734.x

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education, 78*(7), 674–681.

Fogler, H. S., LeBlanc, S. E., & Rizzo, B. (2013). *Strategies for creative problem solving* (3rd ed.). Upper Saddle River, NJ: Prentice-Hall.

Hanna, G. S., & Cashin, W. E. (1987). Matching instructional objectives, subject matter, tests, and score interpretations. *Center for Faculty Education and Development*, Idea Paper No. 18. Manhattan: Kansas State University.

Hewitt, G. F. (1991). Chemical engineering in the British Isles: The academic sector. *Chemical Engineering Research and Design*, 69(A1), 79.

Heywood, J. (2005). *Engineering education: Research and development in curriculum and instruction*. Piscataway, NJ: IEEE Press.

Hirsch, P. L., Linsenmeier, J. A. W., Smith, H. D., & Walker, J. M. T. (2005). Enhancing core competency learning in an integrated summer research experience for bioengineers. *Journal of Engineering Education, 94*(4), 391–401.

Kibler, R. J., Barker, L. L., & Miles, D. T. (1970). *Behavioral objectives and instruction*. Boston, MA: Allyn and Bacon.

Krathwohl, D. R., Bloom, B. S., & Masia, B. (1964). *Taxonomy of educational objectives: The classification of educational goals. Handbook II: The affective domain*. New York: David McKay.

Landrum, R. E., Gurung, R. A. R., & Spann, N. (2012). Assessments of textbook usage and the relationship to student course performance. *College Teaching, 60*(1), 17–24.

Lattuca, L. R., Terenzini, P. T., & Volkwein, J. F. (2006). *Engineering change: A study of the impact of EC 2000, executive summary*. Baltimore, MD: ABET. Retrieved from http://www.abet.org/engineering-change/

Lee, C. S., McNeill, N. J., Douglas, E. P., Koro-Ljungberg, M. E., & Therriault, D. J. (2013). Indispensable resource? A phenomenological study of textbook use in engineering problem solving. *Journal of Engineering Education, 102*(2), 269–288. http://dx.doi.org/10.1002/jee.20011

Lepionka, M. E. (2008). *Writing and developing your college textbook: A comprehensive guide to textbook authorship and higher education publishing* (2nd ed.). Gloucester, MA: Atlantic Path Publishing.

Loui, M. (2005). Ethics and the development of professional identities of engineering students. *Journal of Engineering Education, 94*(4), 383–390. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00866.x

Mazur, E. (1997). *Peer instruction: A user's manual*. Upper Saddle River, NJ: Prentice-Hall.

National Academy of Engineering. (2005). *Educating the engineer of 2020: Adapting engineering education to the new century*. Washington, DC: National Academies Press.

National Academy of Engineering. (2009). *Developing metrics for assessing engineering instruction: What gets measured is what gets improved*. Washington, DC: National Academies Press.

Newberry, B., & Farison, J. (2003). A look at the past and present of general engineering and engineering science programs. *Journal of Engineering Education, 92*(3), 217–224. http://dx.doi.org/10.1002/j.2168-9830.2003.tb00762.x

Palmer, P. J. (1983). *To know as we are known: A spirituality of education*. San Francisco, CA: Harper.

Passow, H. J. (2012). Which ABET competencies do engineering graduates find most important in their work? *Journal of Engineering Education, 101*(1), 95–118. http://dx.doi.org/10.1002/j.2168-9830.2012.tb00043.x

Plants, H. L. (1972). Content comes first. *Engineering Education, 62*(6), 533–534.

Plants, H. L. (1989). Teaching models for teaching problem solving. *Proceedings of the ASEE Annual Conference* (p. 983). Washington, DC: ASEE.

Plants, H. L., Dean, R. K., Sears, J. T., & Venable, W. S. (1980). A taxonomy of problem-solving activities and its implications for teaching. In J. L. Lubkin (Ed.), *The teaching of elementary problem solving in engineering and related fields* (pp. 21–34). Washington, DC: ASEE.

Robinson, D. H. (1994). Textbook selection: Watch out for "inconsiderate" texts. In K. W. Pritchard & R. M. Sawyer (Eds.), *Handbook of college teaching: Theory and applications* (Chapter 32). Westport, CT: Greenwood Press.

Rogers, G. M. (2010). Developing rubrics. ABET webinar presented by Daina Briedis. Retrieved from http://www.abet.org/engineering-change/

Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "professional skills"—Can they be taught? Can they be assessed? *Journal of Engineering Education, 94*(1), 41–55. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00828.x

Sheppard, S. D., Macatangay, K., Colby, K., & Sullivan, W. M. (2009). *Educating engineers. Designing for the future of the field*. San Francisco, CA: Jossey-Bass.

Stevens, D. D., & Levi, A. J. (2012). *Introduction to rubrics: An assessment tool to save grading time, convey effective feedback, and promote student learning*. Sterling, VA: Stylus.

Stice, J. E. (1976). A first step toward improved teaching. *Engineering Education, 66*(5), 394–398.

Taveggia, T. C., & Hedley, R. A. (1972). Teaching really matters, or does it? *Journal of Engineering Education, 62*(6), 546–549.

Walvoord, B. E., & Anderson, V. J. (2010). *Effective grading: A tool for learning and assessment in college* (2nd ed.). San Francisco, CA: Jossey-Bass.

Wankat, P. C. (2002). *The effective efficient professor: Teaching, scholarship and service.* Boston, MA: Allyn & Bacon.

Wankat, P. C., & Haghighi, K. (2009). Multidisciplinary engineering—Flexibility and ABET accreditation. *Proceedings of the 2009 ASEE Annual Conference* (CD Paper 176), Austin, TX.

Wei, J. (2008). Chemical engineering education in postindustrial America. *Industrial & Engineering Chemistry Research, 47*(1), 1–8. http://dx.doi.org/10.1021/ie0713238

Williams, B., Figueiredo, J., & Trevelyan, J. (2014). *Engineering practice in a global context: Understanding the technical and the social.* Leiden, The Netherlands: CRC Press.

Zerubavel, E. (1999). *The clockwork muse: Theses, dissertations and books.* Cambridge, MA: Harvard University Press.

APPENDIX. SAMPLE RUBRICS FOR ABET PROFESSIONAL OUTCOMES

3d) An ability to function on multidisciplinary teams.

Attribute	Unacceptable	Marginal	Acceptable	Superior
Multidisciplinary team experience	No experience	2 or more experiences, but not extensive	Several experiences—at least one extensive	Multiple extensive experiences.
Identify effect of personal actions on team	Clueless	Can identify 1 positive and 1 negative action	Identify 2–3 positive and 2–3 negative actions	Identify > 3 positive and > 3 negative actions
Actual conduct	Consistently misses meetings, unprepared, does not do work	Often not professional. Late or miss meetings, not prepared, does not always do work	Usually professional: on time, prepared, does work said would do, fosters collaboration	Professional at all times. On time, prepared, does work, and fosters collaboration
Organization and workload distribution	No organization. Work distribution very uneven	Minimal organization. Some members limited contributions	Adequate organization with all members contributing significantly.	Excellent organization. All members participate fully
Team interdependence	Do not work together	Significant team problems in leadership, cooperation and interaction	Leadership, cooperation, and interaction are all evident and acceptable	Utilize strengths of each team member fully.
Team product	Poor. No team assessment or monitoring	Does not meet specs. Minimal assessment and monitoring	Meets specs. Self assess and monitor adequately	Surpasses specs. Self-assess and monitor during process.
Assessment by peers	Poor, very low ratings	Below average. Did some work, but not enough to earn team grade.	Good. Earned fair share of points and receive team grade.	Excellent. Did more than share of work and leadership.
Overall	Unacceptable	Marginal	Acceptable	Superior

3f) An understanding of professional and ethical responsibility.

Attribute	Unacceptable	Marginal	Acceptable	Superior
Can explain ethical and professional situation	Cannot determine any appropriate parts of code of ethics	75% of time can determine at least one appropriate part of code	Can determine one or more appropriate parts of code	Can determine multiple appropriate parts of code and prioritize their applicability
Can determine appropriate action	Unable to determine any appropriate action.	75% of time can determine at least one appropriate action.	Can determine one or more appropriate actions.	Can determine multiple appropriate actions and prioritize them.
Actual conduct	Unethical, cheating or plagiarism. Racist or bigoted behavior. Shady, marginally professional, often does not treat others with respect.	Honest, usually professional, and usually treats others with respect, but behavior indicates is following only letter of the rules.	Honest, usually professional and treats others with respect, and behavior indicates follows both letter and spirit of the rules.	Highly professional, honest, treats every one with respect. Believes in both spirit and letter of rules.
Overall	Unacceptable	Marginal	Acceptable	Superior

3g) An ability to communicate effectively by speaking and writing (written communication).

Attribute	Unacceptable	Marginal	Acceptable	Superior
Organization	Purpose unclear. No clear structure.	Purpose stated, but not helpful. Difficult to follow. No continuity.	Clear purpose and structure. Logical information format.	Very clear purpose and structure. Information logical and interesting
Content	No grasp of information.	Major gaps in content. Inappropriate content may be included	Appropriate content choice. Comfortable explaining content to some degree	Consistently appropriate subject knowledge, explanation, and elaboration
Abstract or Summary	None	Present, but marginally helpful	Too long with too much detail or too short without detail	Just right. Provides relevant details whilst concise.
Format & Aesthetics	Inconsistent. Changes in font etc.	Mostly consistent format.	Consistent format with appropriate headings and captions	Completely consistent and pleasing to the eye.
Data presentation and visuals	Sloppy figures and tables—hard to decipher.	Figures and tables legible, but not completely convincing.	Neat figures and tables provide needed information.	Exceptional figures and tables reinforce information in text.
Spelling and grammar	Numerous errors. Not proof read.	Several errors. Needs thorough proof reading.	A few minor errors.	Almost perfect. A joy to grade.
Style	Awkward. Impedes understanding.	Too dry or too florid, or alternatively both	Occasionally too dry or too florid.	Enjoyable to read and helps understanding
Citing and References	Although needed, none.	Inadequate inconsistent citing and referencing	Consistent. Minor problems.	Comprehensive. Logical and consistent.
Overall	Unacceptable	Marginal	Acceptable	Superior

3g) An ability to communicate effectively by speaking and writing (oral communication).

Attribute	Unacceptable	Marginal	Acceptable	Superior
Logical order	Disjointed. No organization	Parts are out of order.	Well organized—logic is obvious.	Enhances communication
Appropriate time use	Far too long or too short	Somewhat long or short	Appropriate length	
Objective	Not stated & not clear	Poorly stated	Clearly stated	
Background and significance	Not explained	Only one explained	Both explained	Both very clearly explained
Conclusions	None	Not clearly explained or not entirely logical	Explained and logical	Superior explanation and logical
Content	Inappropriate or incorrect	Mostly appropriate. Some errors	Appropriate and generally correct.	Appropriate and correct.
Visual aids	None, but should have some	Insufficient. Sloppy. Difficult to read	Easy to read. Relate well to content. Neat	Visuals reinforce content. Neat & clear.
Presentation (voice, poise, mannerisms, etc.)	Many distractions: no eye contact, mumbles. Monotone	Some distractions: little eye contact, mispronounces words	No distractions: Clear voice with proper variation. Has eye contact.	Clear voice—pleasant to listen to. Feels like person is speaking directly to you.
Response to questions	Nonresponsive Does not listen	Incomplete, poor listener	Clear and direct. Listens to questions	Repeats question. Complete yet concise.
Overall	Unacceptable	Marginal	Acceptable	Superior

3h) An understanding of the impact of engineering solutions in a societal/global/economic/environmental context.

Attribute	Unacceptable	Marginal	Acceptable	Superior
Explain impact of engineering on environment and society that is globalizing	No reasons and examples, or incorrect reasons and examples	Mainly ineffective evaluation and explanation of impact.	Mostly effective evaluation and explanation of impact with 2 or 3 reasons and 2 or 3 examples	Effective assessment and explanation of engineering impact, multiple reasons and examples.
Explain impact globalization will have on engineering	No reasons and examples, or incorrect reasons and examples	Mainly ineffective evaluation and explanation of impact.	Mostly effective evaluation and explanation of impact with 2 or 3 reasons and 2 or 3 examples	Effective assessment and explanation of engineering impact, multiple reasons and examples.
Broadens understanding of diverse and global cultures	No effort to broaden understanding	Participates in one activity to broaden understanding.	Participates in two or more activities, one is somewhat extensive.	Foreign lang. or participates in study abroad or extensive travel or multiple activities to broaden understanding.
Personal plan for success in a global society	No plan	Vague plan. No contingency plan	Plan with some ideas and directions	Well thought out plan including contingency plan
Overall	Unacceptable	Marginal	Acceptable	Superior

3i) An understanding of how one learns and recognition of the need for lifelong learning.

Attribute	Unacceptable	Marginal	Acceptable	Superior
Explain personal learning style*	No clue or extremely vague	Explains only one important personal learning style.	Explains 2 or 3 important aspects of personal learning style	Identifies/ explains all 4 items of personal style.
Explain methods to improve learning	Cannot identify or explain any methods	Can identify and explain 1 method to improve learning	Identify/ explains 2 or more methods to improve learning, with examples.	Identify/ explains multiple approaches and examples to improve learning.
Self-assessment and metacognition	No clue	Vague idea of how to self-assess and of learning progress	Reasonably accurate self-assessment. May monitor learning	Accurate self-assess, identifies areas to improve, and monitors own learning.
Life-long learning reasons	No reasons	Identifies one acceptable reason	Identifies 2–3 acceptable reasons.	Identifies multiple acceptable reasons
Personal plan for life-long learning	No plan	Vague plan. Some ideas for future. Might pursue more education in future	Has tentative plan and perhaps a contingency plan. Investigating professional development opportunities.	Extensive, specific plan and contingency plans for including professional development and additional education.
Personal life-long learning activities (for students, know of the activities)	No actions beyond going to class.	One or two activities such as attending convocations or belong to club(s).	Above and beyond just engineering. May do a minor. Attends some convocations or belong to club(s).	Above and beyond just engineering. Earning a minor. Routinely attends convocations and belongs to club(s).
Overall	Unacceptable	Marginal	Acceptable	Superior

* Personal learning style is based on Index of Learning Styles (Felder and Silverman, 1988).

3j) A knowledge of how contemporary issues affect engineering and how engineering can impact these issues.

Attribute	Unacceptable	Marginal	Acceptable	Superior
Demonstrates interest and knowledge of contemporary issues	Not interested and no demonstration of knowledge	Some interest. Demonstrates aware of major news items. No historical understanding.	Interested. Demonstrates reasonable breadth and depth. May have some historical understanding.	Demonstrates excellent breadth and depth of knowledge. Has some historical understanding.
How contemporary issues affect Engineering	Demonstrates no or very little understanding of how issues affect engineering.	Demonstrates basic understanding of how issues affect engineering for one contemporary issue.	Demonstrates basic understanding of how several issues affect engineering and in depth for 1 issue. Works to broaden understanding	Demonstrates excellent understanding of how many issues affect engineering and works to broaden understanding.
How Engineering affects contemporary issues	Demonstrates no or very little understanding of how engineering affects issues.	Demonstrates understanding of engineering implications for one contemporary issue.	Demonstrates understanding of engineering implications for several issues and in depth for 1 issue. Works to broaden understanding	Demonstrates excellent in depth understanding of engineering implications for many issues and works to broaden understanding.
Overall	Unacceptable	Marginal	Acceptable	Superior

CHAPTER 5

PROBLEM SOLVING AND CREATIVITY

An explicit discussion of problem-solving methods and problem-solving hints should be included in every engineering class. Heywood (2005) agrees, although he notes that the position can be debated. A problem-solving taxonomy was briefly discussed in Section 4.2.4. Most engineering schools are very good at teaching the lowest levels—routines and diagnosis—and most engineering students become very proficient at them. But students in general are not proficient at strategy, interpretation, and generation—three areas of the problem-solving taxonomy to be discussed throughout this chapter.

We will first briefly discuss some of the basic ideas about problem solving and compare the differences between novices and experts. Then present a strategy for problem solving which works well for well-understood problems, and discuss methods (heuristics) for getting unstuck. The teaching of problem solving will be covered with a number of hints that can be used in class. Finally, creativity will be discussed.

5.1. SUMMARY AND OBJECTIVES

After reading this chapter, you should be able to:

- Discuss and modify Figure 5-1 to fit your understanding of problem solving.
- Delineate the differences between novices and experts. Use these differences to outline how to teach novices to be better problem solvers.
- Discuss the steps in a problem-solving strategy (one different from the one discussed here can be used as a substitute) and use this strategy to help students solve problems.
- List and help students use some of the methods for getting unstuck.
- Develop a plan to incorporate both problem-solving and creativity exercises in an engineering course.
- Explain the three steps which can foster creativity and use some of the techniques.