Maximizing the Benefit of Developing an Educational Plan to Meet the ABET 2000 Criteria

W.V. Wilding, J.N. Harb, R.E. Terry, W.C. Hecker
Department of Chemical Engineering
Brigham Young University
Provo, Utah 84602

Abstract

This paper documents our experience with the development of an educational plan designed to satisfy the requirements of ABET 2000. The paper first presents the overall structure of the plan which includes both a process loop and a product loop, with assessment and feedback at multiple levels. Our progress on the initial pass through the process loop is then described. This description begins with a procedure developed and used for definition of learning outcomes in the form of attributes and competencies. Also documented are the methods used for successfully promoting faculty involvement in and ownership for the process. Mastery levels have been defined in order to quantify the relative importance of individual competencies. Based on these levels, a core set of outcomes targeted for mastery by all graduating students was identified. These core outcomes will impact the structure of our curriculum and influence instruction and evaluation at all levels.

Introduction

ABET 2000 provides an excellent opportunity to improve engineering education by focusing on the product (student attributes) rather than the process (teaching). Although the formality of outcomes-based education may be unfamiliar to some, the fundamental ideas are not new, and are routinely incorporated into our day-to-day efforts to improve student learning. ABET 2000 provides the formal context needed for broad application of these ideas and, of course, the driving force needed to facilitate change.

At issue, then, is how we will respond to this opportunity. On one hand ABET 2000 may be viewed as an unpleasant and perhaps unnecessary task that must be accomplished to achieve accreditation. Alternatively, it may be viewed as a catalyst for making significant improvements to engineering education. It is our opinion that the second outlook is essential in order to maximize the benefits of implementing ABET 2000. Otherwise, it is unlikely that the full benefits will be achieved.

Our experience has shown that the approach used to implement an educational plan consistent with the ABET 2000 criteria has a significant impact on the attitude of the faculty towards the process. Based on this experience, we have developed an approach to maximize faculty interest in and ownership for the process in our department. The purpose of this paper is to share our approach and to discuss some of the results and benefits that we have observed to date.

Structure of the Plan

Figure 1 represents the overall view of the educational plan that we are working to develop and implement. The plan includes a systematic process, shown on the left side of the diagram, with feedback at multiple levels. The process is used to define desired outcomes and to develop methods for helping students to achieve those outcomes. The methods are implemented on the product side of the diagram and the effectiveness of the plan is judged by evaluating student performance against the desired outcomes. It should be noted that the initial pass through the process requires some additional steps that are not reflected in the figure. These are associated with prioritizing and evaluating the specified outcomes, as discussed later in the paper, and with development of the assessment strategy, which is yet to be done. As shown in the diagram, once assessment procedures are in place it is anticipated that feedback and change will be most active at the classroom level (instructional activities), with less frequent adjustments in the curriculum, and infrequent modifications to competencies and attributes (target outcomes).

We are currently in the middle of our initial pass through the process. With input from our constituencies, we have defined desired outcomes in the form of attributes and competencies. A key aspect of this paper is a description of the procedure that was followed for outcome definition in order to involve the entire faculty and foster ownership. We are currently in the process of associating the attributes and competencies with practices that will form the basis of a revised curriculum designed to help students to develop the desired attributes. Subsequent steps include modification of our current curriculum to correct for deficiencies, and the implementation of formal procedures for assessment and feedback.

The emphasis of our efforts to date has been on involvement of the faculty in discussions targeted at improving the education of our students by helping them to achieve the desired outcomes. Our experience has produced some interesting insights that were not apparent as we began moving through the process. It is our hope that these insights might be useful to others at similar stages in the development of an educational plan consistent with ABET 2000.

Definition of Attributes and Competencies

The first major task in the process of developing an educational plan was to define the learning outcomes in the form of attributes and competencies. Prior to formally tackling this, we solicited information from several of our constituencies including alumni, students, faculty, and recruiters in two separate instruments.

Firstly, recruiters of our students were interviewed to determine their feeling on the relative importance of the following four areas to the initial hiring of an engineer and to their current success in the company:

- Technical Ability
- Communication Skills
- Initiative
- Interpersonal Skills

Secondly, a brief survey was created and given to alumni, faculty, and current students to

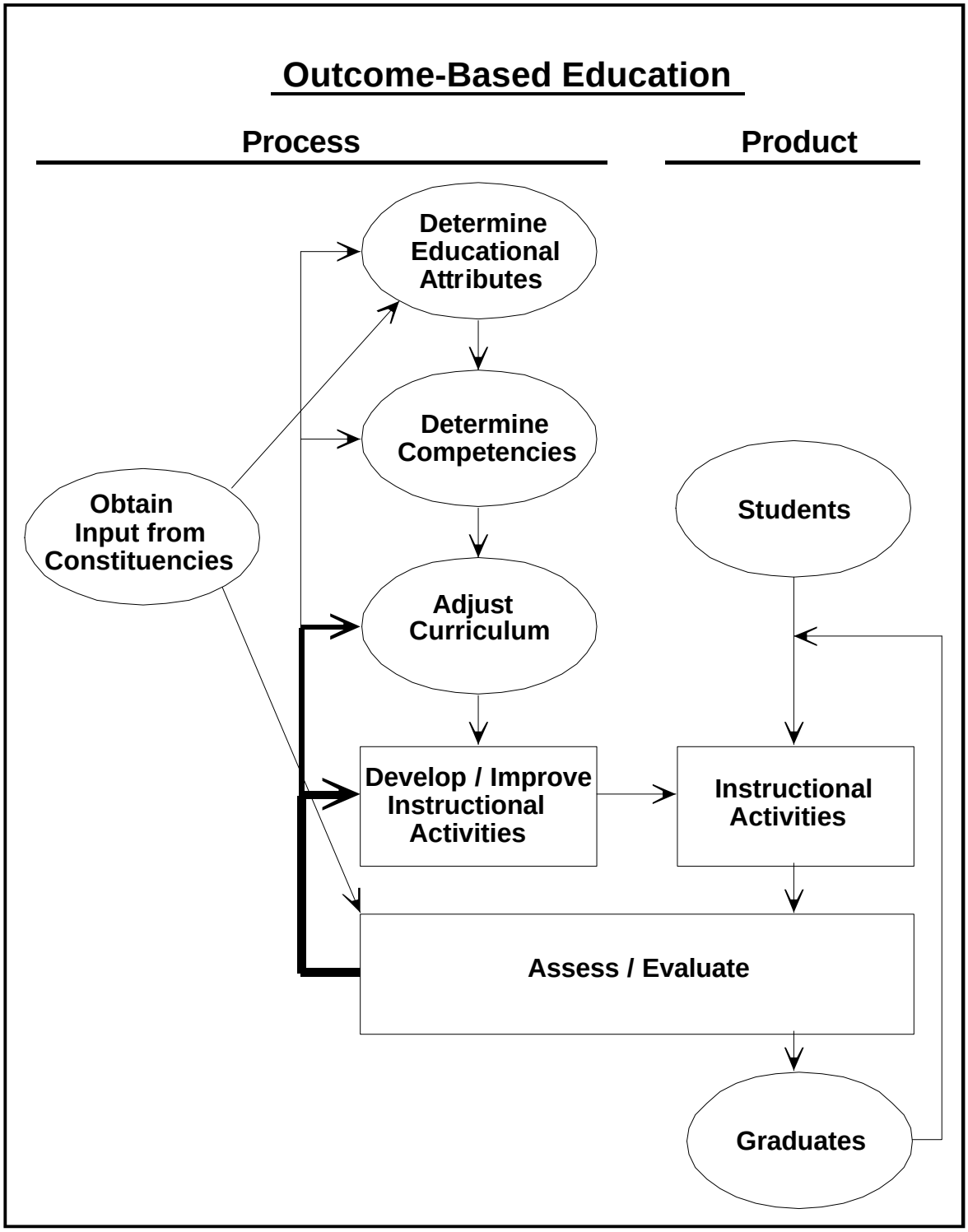

Figure 1. Outcome-Based Education Plan

determine their opinions regarding Criterion 3 (a-k) of ABET 2000. We asked each group to indicate:

1) the relative importance of the 11 criteria, and
2) how well our program addresses each of these criteria (i.e., their level of satisfaction).

Responses from the three groups were compared and showed some very interesting trends (R.E. Terry and W.C. Hecker, "Survey Results of Outcome Assessment at BYU", presented at the annual AIChE conference in Los Angeles, Nov. 1997). In general, we found that the alumni and students felt that we were doing better at helping them achieve the attributes of Criteria 3 (a-k) than we as a faculty felt that we were doing.

With this feedback from our constituency groups, we moved to the task of defining the targeted attributes and competencies for each of those attributes. Our first attempt was to simply use Criterion 3 (a-k), along with the Program Criteria under ABET Criterion 4, as our attributes. We divided our entire faculty (13) into groups of two or three with the assignment of specifying competencies for each of the attributes. Several problems quickly became evident. First, the attitude of the faculty was that we were doing "extra" work simply to satisfy ABET. There was no feeling of ownership for the process and no sense of forthcoming benefit from the exercise. The general feeling was that we were being compelled by external forces to satisfy external requirements. Also, there were some serious reservations about the relative importance of the different criteria and a definite feeling that they should not be weighted equally. There was no clear connection between our current curriculum and the ABET 2000 process. Finally, it was evident that interest in the process varied significantly from faculty member to faculty member, with attitudes ranging from positive to antagonistic.

It was at this point that we made several changes which proved to be critical to the success of our process. The decision was made that we were not going to let the external requirement prevent us from getting the maximum possible benefit from the process. The majority of the faculty believed that the type of process recommended by ABET could be used to enhance the education of our students and we were committed to make the most out of this opportunity. However, we recognized that we needed to feel ownership of and be committed to the learning outcomes defined for our students if we were to have any opportunity for success. We also recognized that we needed to involve all of the faculty, but at different levels. Our undergraduate committee, consisting of five faculty members with a relatively high level of interest in the process, was given the assignment to do the initial work and prepare items for discussion by the full faculty. This two-tier structure (committee and faculty) has worked very well and is strongly preferred over use of a single individual. Our experience has shown that the discussion and synergism derived from the committee has been extremely beneficial. The workload has also been more evenly distributed. Finally, to increase our ownership of the process, we decided to develop our own attributes instead of using those defined by ABET.

To define competencies and attributes, we first listed the skills and experience expected of students semester by semester and course by course as they move from their freshman year to graduation. This exercise was performed during several meetings of the undergraduate committee. These skills and experiences represented the specific characteristics that we desired

for our students and were labeled "competencies." The progression from beginning to end provided a natural connection to our current curriculum, but did not constrain us from objective consideration of the competencies desired at each stage. Once a 'complete' list had been assembled (which included about 70 items), similar competencies were placed together into groups. Each group was given a name by defining an attribute which characterized that group of competencies. The net result was the twelve attributes listed in Table 1.

Table 1. Desired Attributes for Chemical Engineering Students at BYU	
1	An understanding of the chemical engineering major and profession
2	An understanding of fundamental principles of mathematics and science
3	An understanding of chemical engineering fundamentals
4	Practical experience with chemical process equipment, chemical handling, chemical analysis, and process instrumentation
5	An ability to use modern engineering tools necessary for engineering practice
6	An ability to define and solve engineering problems
7	An awareness and a sensitivity to safety and environmental issues
8	An ability to communicate ideas effectively in both oral and written form
9	An ability to work effectively with others to accomplish common goals
10	An ability to apply chemical engineering fundamentals to solve open-ended problems and to design process units and systems of process units including multiple operations
11	An appreciation for and a commitment to ethical and professional responsibilities
12	An appreciation for and a commitment to the continuing pursuit of excellence and the full realization of human potential

A summary sheet was prepared for each attribute which included the statement of the attribute, a description of the attribute, and a list of the specific competencies associated with that attribute. Table 2 shows an example of such a summary sheet for Attribute 8. These summary sheets were distributed to the entire faculty and discussed in detail in faculty meeting at a rate of one or two per week. Refinements were made based on our discussions to complete our initial pass through the attributes and competencies.

Because the competencies and attributes were developed "from the ground up" based on characteristics that we wanted in our students, there was no guarantee that successful achievement of these attributes would satisfy the requirements of ABET 2000. However, comparison of our attributes with those specified by ABET showed that, although there was not a one-to-one correspondence, our attributes encompass ABET 2000 Criteria 3, 4 and 8 (Program Outcomes and Assessment, Professional Component, and Program Criteria, respectively) and thus, our program will satisfy ABET requirements. This conclusion was not surprising and will generally be true since the ABET 2000 criteria represent a generally applicable subset of characteristics desired for engineering students. Perhaps more importantly, we have found that the process of developing our own attributes has produced some critical additional benefits,

Table 2. Attribute Summary Sheet for Attribute 8
Attribute 8: An ability to communicate ideas effectively in both oral and written form. Description: Students will express ideas clearly and concisely in an organized manner both orally and in writing. Students will be effective readers and listeners.
Competencies: **Graduates must be able to:** • Give an effective, well-organized oral presentation of technical material including the handling of questions and the use of appropriate visual aids • Demonstrate experience in hearing and critiquing professional technical presentations • Demonstrate ability to communicate technical ideas in informal discussions • Demonstrate experience and ability in interviewing skills • Write effective, well-organized technical reports, including formal engineering reports, short letter reports, and a personal resume • Demonstrate effective reading of technical material and interpretation of graphical representations

including:

- faculty ownership (buy-in)
- inclusion of goals specific to our institution
- insight into the proper weighting of attributes
- a clear connection to our current curriculum
- a "complete" consideration of important issues

We believe that these benefits are the direct result of going through the process of defining our own attributes and that they would not have resulted from the simple adoption of an external set of attributes (e.g., ABET Criterion 3, a-k). The process that we followed is discipline independent and therefore applicable for use by any engineering department. However, it is a time consuming process, but we believe the impact on our students' education will be worth the effort. Due to the time involved, it is important that this process be started early so that the educational plan will be operational in time for accreditation visits.

Categorization and Initial Evaluation of Attributes and Competencies

Once we had completed the initial definition of learning outcomes, the next task was to associate practices with each competency. The purpose of the practices is to help students to develop the desired competency. As we began to identify practices, it became clear that the level of mastery expected from students varied from competency to competency. A simple exposure to the material was all that was required for some competencies. For others, it was our expectation that students should not graduate without demonstrating a specified level of mastery. The expected level of mastery is intimately connected to the types of practices, assessment, and feedback

associated with a given competency. Consequently, four different mastery levels (see Table 3) were defined and used to classify the competencies.

Table 3. Mastery Levels for Competencies

Mastery Level	Description
0	Optional
1	Evidence of Exposure
2	Competency With Course Grade Standard and Systematic Feedback
3	Competency With Multipoint Assessment, Systematic Feedback and Student Recycle (minimum competency for graduation)

Definition of these mastery levels was another critical step in our path toward an educational plan. Each competency was next evaluated and assigned a mastery level appropriate for our program. In the process of doing this, we were able to identify specific competencies for which mastery was deemed essential (level 3). An example of such a competency in chemical engineering is the ability to do a simple material balance. We refer to these level 3 competencies as "Core Competencies" because they represent the core capabilities of graduating engineers. As we determine the structure of our curriculum, emphasis will be given to practices and assessment methods that are focused on these core areas.

Identification of core competencies has several interesting implications with respect to assessment. Since all graduates will be required to possess the core competencies, we will be required to test all of our students prior to graduation and "recycle" those who do not meet the minimum requirements. However, all of our faculty agree that we do not want a large recycle stream of students at the end of their senior year. Instead, we currently envision a system where the assessment of performance in core areas is made throughout the curriculum and remedial action is taken as soon as a deficiency is noted. This assessment is likely to be in the form of exam problems written specifically to assess performance in core areas. One way to accomplish this would be to change the way we write exams to include at least two classes of problems: 1) problems that test minimum competencies in core areas, and 2) more challenging problems that can be used as a basis for assigning grades. All students would be required to complete the minimum competency aspect of the exam(s) at the required level in order to pass a class. Students will no longer be able to survive by getting partial credit on difficult problems. Rather, they will need to demonstrate mastery in the core areas. We believe that such an approach will lead to a significant improvement of student learning.

Once the mastery levels had been defined, we proceeded to categorize and evaluate in a preliminary way the attributes and competencies. This process consisted of the following steps:

- Specification of the mastery level for each competency
- Identification of current and proposed practices associated with each competency

- Identification of potential assessment tools for each competency
- Qualitative evaluation (grade) of our current performance level for each competency

This was accomplished in practice by dividing the attributes amongst the members of our undergraduate committee. A form similar to that shown in Table 4 (for Attribute 7) was completed by the faculty member assigned to a particular attribute. The committee member who completed the form led the discussion of that attribute in our committee meeting. Our weekly meeting permitted the discussion of one or two attributes per week. Discussions were typically lively and resulted in refinement of attributes and competencies. Mastery levels were assigned to each competency and a preliminary evaluation of our current performance on each competency was made. Following our discussion, the form was revised to reflect the conclusions reached by the committee and distributed to the entire faculty for discussion at the next faculty meeting. The faculty meeting discussion was also led by the committee member responsible for the particular attribute. Again, the participation level in these discussions was high, and these discussions led to further refinement of the attributes and competencies. It was our observation that this procedure permitted faculty members to provide significant input into the process and feel ownership for the product without requiring a significant investment in time from all of the faculty.

Table 4. Evaluation Form for Attribute 7

Attribute 7: A working knowledge of safety and environmental aspects of engineering practice.

Competency	Level	Practices	Current Practice	Grade	Potential Assessment Means
Laboratory and chemicals handling	2	UO lab instruction Chemistry lab instruction	Yes Yes	C B	Grade in course Grade in course
HAZCOM training	3	HAZCOM training	No	E	Pass HAZCOM exam
Safety and environment considerations in engineering problem solving	2	ChE 451: Safety, Fault-tree and HAZOP Assigned problems and instruction throughout curriculum	Yes Yes	B C	Grade in courses Portfolio
Environmental laws & regulations	1	ChE 170: Introduction; ChE 451: Formal instruction	Yes Yes	B A	Grade in course
Capstone design with safety/ environmental considerations	2	ChE 451: Design project	Yes	C	Grade on project

The information summarized in Table 4 for Attribute 7 is the result of much discussion and several iterations. Note that a mastery level of 3 was assigned for HAZCOM training, meaning

that our students will be required to pass the HAZCOM test as a condition for graduation. HAZCOM training has not been generally required of our students to date. There was considerable debate amongst the undergraduate committee and the full faculty before it was agreed that we should require HAZCOM training and that this level of mastery was appropriate. This decision was impacted by input from our industrial constituency which indicated that new graduates have not developed an appreciation for the importance of chemical safety.

As the faculty discussed chemical safety as part of this attribute we realized that the layout of our unit operations laboratory could be improved to emphasize safe chemical handling practices. Plans for doing this are being developed. Thus, the discussion of Attribute 7 has already been the impetus leading to worthwhile changes.

The competency dealing with environmental legislation provides another interesting example. Up until about five years ago there was very little discussion of this body of legislation in our required curriculum. Such discussions have been recently incorporated into our capstone process design course. The debate on this competency centered on the appropriate mastery level. Environmental legislation will be an important aspect of the engineering work of our graduates; however, it was decided in our discussions that it is probably sufficient in our curriculum to introduce the legislation. Proficiency in understanding and applying environmental legislation could appropriately be obtained on the job. A mastery level of 1 was therefore chosen for this competency.

This process has been applied to each of the attributes, producing a worksheet for each that is the culmination of much discussion and debate. However, it is likely that as we match attributes with practices and develop assessment methods that there will be further refinements.

Summary and Conclusions

This paper documents our experience with the development of an outcomes-based educational plan to satisfy ABET 2000. We began the development by defining the overall structure of the educational plan which includes both a process loop and a product loop. The process loop has feedback at multiple levels, and is used to define learning outcomes and to develop methods for helping students to achieve those outcomes. The methods are implemented in the product loop and the effectiveness of the plan is judged by evaluating student performance against the desired outcomes.

Our initial pass through the process loop began with the definition of outcomes in the form of attributes and competencies. We originally attempted to simply adopt the attributes from ABET Criterion 3 (a-k), but found that development of our own set of attributes was critical to our ownership of the process. These attributes were obtained by proceeding through our undergraduate program and identifying the desired competencies at each step and then grouping them into 12 attributes. The list of attributes and competencies was refined using a two-tier approach with initial work being done by the undergraduate committee leading to discussions with the entire faculty. This approach helped to streamline the process and allowed all of the faculty to be effectively involved. Our list of attributes includes all of the elements of ABET 2000, so we will be able to satisfy accreditation requirements, yet significant additional benefits have resulted from our process. These benefits include 1) enhanced faculty ownership of the

process (buy-in), 2) effective inclusion of goals specific to our institution, 3) insight into relative importance of competencies and the definition of mastery levels for competencies, 4) a clear connection to our current curriculum, and 5) a broad consideration of important issues.

Once our attributes and competencies were defined, practices were associated with each competency. The purpose of the practices is to help students to develop the desired competency. It was also necessary to define mastery levels in order to reflect the relative importance of individual competencies. Based on these levels, a core set of outcomes, targeted for mastery by all of our students, was identified. Definition and agreement on these core outcomes will have a significant impact on the structure of our entire curriculum and influence instruction and evaluation at all levels.

Although there is still much to do, we have already benefited considerably from this process. We are optimistic and confident that our continued efforts will produce many additional benefits that will lead directly to improved student learning and preparation.

W. VINCENT WILDING
Vincent Wilding is an Associate Professor of Chemical Engineering at Brigham Young University. His research interests include thermophysical properties, phase equilibria and environmental engineering. He received his B.S. degree in Chemical Engineering from Brigham Young University in 1981 and his Ph.D. in Chemical Engineering from Rice University in 1985.

JOHN N. HARB
John N. Harb is an Associate Professor of Chemical Engineering at BYU. He received his Ph.D. from the University of Illinois at Urbana in 1988. He has been active in ASEE and has written several papers and a monograph related to engineering education, as well as a textbook for first-year chemical engineering students. He conducts research in electrochemical engineering where he is developing microscopic batteries for use with MEMS.

RONALD E. TERRY
Ron Terry is a Professor of Chemical Engineering at Brigham Young University. He has conducted scholarly work and published numerous articles in engineering education. He is an active member of the ERM Division within ASEE. He currently serves as the Chair of the ASEE Rocky Mountain Section. He holds B.S. and Ph.D. degrees in Chemical Engineering from Oregon State University and Brigham Young University, respectively.

WILLIAM C. HECKER
William C. Hecker is an Associate Professor of Chemical Engineering at BYU where he has taught since 1982. Previously he worked at Chevron Research, Dow Chemical, and Exxon. He received his Ph.D. from UC Berkeley. Research interests include chemical kinetics, coal char oxidation, nitric oxide reduction, heterogeneous catalysis, infrared spectroscopy of adsorbed species, and humanitarian technical aid.