Program Improvements Resulting from Completion of One ABET 2000 Assessment Cycle

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Introduction

With the advent of ABET 2000, self-assessment of engineering programs has become important. To this end, it is essential to define the assessment methods and metrics against which a program will be judged. Various assessment tools exist, ranging from standardized tests to performance-based assessment to more subjective instruments, such as student surveys of their learning and/or knowledge. No assessment tool is ideal. For example, standardized exams have been criticized due to concerns of reduced instructor autonomy[1] and alteration of curriculum goals (teaching to the test);[2] in addition, the results of standardized tests may be influenced by student motivation.[3] On the other hand, student self-evaluations of learning and/or knowledge are subjective. It has been argued by several researchers that combining different types of assessment tools results in a more successful assessment.[4,5]

Equally important, perhaps, the assessment data obtained must be analyzed and presented in an efficient manner to facilitate identification of program problems and implementation of improvements.[6] In this paper, we present the assessment and metrics used in the Departments of Chemical Engineering and Petroleum Engineering at Texas Tech University and the program improvements that have resulted from the completion of the assessment cycle.

Assessment and Metrics

The metrics used to evaluate a program should be directly tied to that program's objectives, and the clearer that these are defined, the easier it is to develop appropriate metrics. As an example, there are three program objectives for the Department of Chemical Engineering at Texas Tech University:

Program Objective 1: Provide students with a high quality education that will enable them to adapt to a rapidly changing technical environment.

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Program Objective 2: Produce graduates who will be productive throughout their careers in a wide range of industrial and professional environments.

Program Objective 3: Develop graduates with a strong sense of ethics and professionalism and the ability to succeed as both individual and team contributors.

Similar objectives are in place in the Department of Petroleum Engineering. For each of these program objectives, we have developed several strategies to achieve the objectives. For each strategy, we outline student-centered outcomes which are expected to result if the strategy is well-implemented. The metrics employed are an attempt to measure these student-centered outcomes. An example is shown in Table 1 (at the end of the article) and more details can be found on the Chemical Engineering web site.[7]

One of the primary metrics used in all of the engineering departments at Texas Tech University is a mock Fundamentals of Engineering (FE) exam required of all graduating seniors to assess competency in core subjects (Metric 4 for Strategy 1A in Table 1). The exam is administered by the College of Engineering each semester. For the chemical engineering program, the metric is an average score better than 50 % on the mock exam subject areas which are core areas of chemical engineering and 100 % of the students obtaining a score of better than 50% on the ethics segment. Previous studies in the College of Engineering by Heinze et al. have demonstrated that a score of 50 % on the mock FE correlates with a 90 % passing rate on the FE exam.[8] The advantage of a mock FE over the FE Exam is that a numerical score rather than simply pass/fail can be provided. An additional benefit of administering the mock FE exam is that students get feedback on their areas of strength and weakness prior to taking the FE exam. In addition, students who obtain a score of 50 % on the mock FE are encouraged to take the FE exam. Over the last two years, Texas Tech has had the highest percentage of engineering students taking the FE exam, coupled with the highest passing rate, of the public institutions in Texas. The Department of Petroleum Engineering's results are even more impressive, with over 95 % of graduating seniors passing the FE exam each of the last three years, up from less than 30 % in the early 1990s.[1]

Another useful assessment tool is the senior exit interview and student course surveys, both of which are aimed at interrogating teaching and learning effectiveness either for the curriculum as a whole or in particular classes. The course surveys are coupled with instructor self-evaluations in order to identify problems in the curriculum. Table 2 gives the Chemical Engineering course survey questions. The metrics that are used for the survey are as follows:

- Score of 4.0 or higher for items relating to ABET criteria a, b, c, e, and k in one course per semester for sophomores and higher;
- Score of 4.0 or higher for items relating to ABET criterion d in senior level laboratory and design courses;
- Score of 4.0 or higher for items relating to ABET criterion g in the sophomore-level technical communications course and in the senior level unit operations laboratory;

- Score above 4.0 for items relating to ABET criteria f and h in the freshman-level chemical engineering seminar, in the sophomore-level technical communications course, and in the senior level laboratory and design courses.

It is not necessary that scores of 4.0 are achieved for all questions (or for all ABET criteria a-k) for each course, but rather, that courses accomplish their goals in the curriculum. For example, Table 2, which also presents the survey results from the freshman-level chemical engineering seminar for the last three years, indicates that low scores were achieved in that class on items related to ABET criteria b, c, and k. Since the student-centered objectives for the freshman-level seminar do not include these particular criteria as goals, the low scores are expected and are not problematic.

To insure competency in the area of health and safety, Chemical Engineering students must master selected material, such as the reading of MSDS sheets, as a requirement for passing the senior-level unit operations laboratory where a health and safety competency test is administered. In addition, a HAZOP competency test is given and must be passed in the senior-level design course. These tests are augmented by health and safety write-ups required in reports for the senior-level unit operations laboratory.

In the Department of Chemical Engineering, we are also in the process of implementing another survey for each course aimed at assessing the students' understanding of specific chemical engineering topics. For each course, the survey will be completed both by the students and by the instructor; it expected that there will be a correlation between the students' and the instructor's responses. Such a survey is anticipated to help the undergraduate committee ensure that our curriculum is of sufficient quality and breadth to meet the departmental objectives outlined in the introduction. In addition, the results of the survey are more easily tabulated than the current instructor self-evaluation completed for each course, and it is, thus, anticipated that having the information in a more accessible form should facilitate identification of problems. A version of this survey will also be given to the alumni to determine specific topics, if any, they feel were not adequately covered in their undergraduate curriculum.

Program Improvements

Program improvements have resulted from implementation of the assessment tools and metrics discussed. Examining the data shown in Table 2 for the freshman-level chemical engineering seminar for the fall of 2000, it is clear that the students felt the course contributed very little to their learning and development except in the area of profession and ethical responsibility that semester (which was the first semester the assessment was administered). The Chemical Engineering undergraduate committee discussed the problem in some detail, using as a basis for the discussion the instructor self-evaluation of the course and the students' comments and survey results. The committee then gave recommendations to the faculty for changes in the course content – from a seminar in which each faculty member gave an invited lecture concerning their research and/or teaching interests to a course based on chemical engineering case studies with the bulk of the lecturing performed by a single instructor. Significant positive improvements in the students' perceptions of what they obtained from the course occurred and have been sustained by the change in the course content.

Senior exit interviews, conducted by the Chair of the Department of Chemical Engineering, have also led to changes. For example, the course content in a required chemistry course, Physical Chemistry 2, focused on quantum mechanics and statistical mechanics and neglected key topics relevant to Chemical Engineering, for example, reaction rate theory. The undergraduate committee worked with faculty in Chemistry to modify the course to include these topics without sacrificing the content required for the Chemistry majors. Another change that resulted from senior exit interviews, coupled with the course survey results, was the documentation of poor instruction by a particular instructor. In this case, the instructor was temporarily removed from the classroom and from teaching required chemical engineering courses. Upon making improvements in his or her teaching, as documented by course surveys of the elective courses taught, the instructor was re-integrated into the teaching of required chemical engineering courses.

Significant changes in the Chemical Engineering curriculum have also resulted from implementation of our assessment/improvement/assessment cycle. For example, we recently combined three junior-year transport laboratories, associated with fluid mechanics, heat transfer, and mass transfer, into a single two-credit laboratory course taught in the spring of the junior year. The change was made because the course survey results consistently demonstrated over several semesters that the students did not feel that these laboratories contributed "a great deal" to their ability to design and conduct experiments in spite of changes in instructors, and we expected that these courses would make such a contribution. Based on discussions with the students and faculty, the undergraduate committee identified that the problem was primarily logistical; the laboratories were generally taught as demonstrations because there were not adequate facilities for the students to perform the experiments at the same time. By changing the course to a single course taught subsequent to the fluid mechanics and heat transfer courses, students could be rotated through various experiments in a way that was not possible when the laboratory and course were taught concurrently. Assessment of this change has not yet been performed, but we anticipate that, similar to the senior-year Unit Operations Laboratory, the junior-year transport lab will significantly contribute to the students' ability to design and conduct experiments.

Conclusion

Program self-assessment is an integral part of ABET 2000. Several program improvements resulting from the assessment cycle in the Departments of Chemical and Petroleum Engineering at Texas Tech University have been described. Assessment tools include the mock FE exam, student course surveys, student exit interviews, and alumni surveys. Course improvements were described in two courses resulting from changes in course content implemented due to the results from program self-assessment. In addition, an ineffective instructor was identified, and improvements were made in the instructor's teaching style. A final example demonstrated that a significant problem in the Chemical Engineering curriculum was identified based on the assessment tools and metrics in use and a plan to correct the problem put in place.

Table 1: Strategies, Outcomes, and Assessment Methods and Metrics for Meeting Program Objective 1 in Chemical Engineering (after ref. 7)

Strategies for Implementing Program Objective 1	**Student-Centered Outcomes**	**ABET Criterion a-k**	**Assessment Methods and Metrics**
1A Provide students with breadth in the ChE curriculum through required course offerings that cover the basics of chemistry, mass and energy balances, thermodynamics, staged separations, transport phenomena, reaction kinetics, unit operations, professional practice, and process control and design.	1. Our graduates will have the basic understanding of all the principles traditionally used by ChEs and an appreciation for how and where these are used.	a, b, c, e, k	1. Senior design project assessment. 2. Successful completion of coursework. 3. Student exit interviews. 4. Average score of better than 50% on mock FE (correlated with passage rate of greater than 95% on FE). 5. Undergraduate committee review of ChE course survey results; one course per semester for sophomores and higher to score above 4.0 for ABET criterion a, b, c, e, and k.
1B Incorporate design modules and/or open-ended problems in the one course in each of the sophomore, junior and senior years of the undergraduate curriculum	1. Students can implement strategies required to solve open-ended problems. 2. Students can use ChE design software, such as ChemCad, Hysys, SuperPro Designer, and Aspen.	a, b, c, e, k	1. Successful completion of capstone design project. 2. Compilation of design projects in core undergraduate courses other than in the capstone design course by undergraduate committee.
1C Utilize engineering electives, science electives, and Chemical Engineering electives, in areas such as Polymers, Bioengineering, Environmental Engineering, Process Modeling, and Statistics, to show the relationship between basic science and engineering/ technology.	1. Students understand how basic science is applied in solving Chemical Engineering problems.	a, b, e, k	1. Student self-evaluation of basic science skills and math skills at the end of each semester in Ch E elective courses.
1D Encourage use of outside resources, such as WWW, library, etc., in solving open-ended problems in undergraduate ChE classes.	1. Students will know how to effectively use the WWW and the library to find information.	i, k	1. Compilation of an outside resource portfolio by the faculty member teaching technical writing containing examples of the use of WWW and library, as well as documentation of use of external resources in other courses on instructor self-evaluation.

Table 2: Chemical Engineering Course Survey Results for Chemical Engineering Freshman Seminar (after ref. 7)

Key
1.0 course did not at all contribute to learning and development in selected area
5.0 course contributed a great deal to learning and development in selected area

Question: To what degree did the given course contribute to your learning and development in the following areas?	ABET a-k	Fall 2000	Fall 2001	Fall 2002
Fundamental knowledge of ChE principles	a	2.9	3.2	3.5
Mathematical skills	a	1.6	2.4	2.1
Ability to design and conduct experiments	b	1.8	2.8	2.3
Ability to analyze and interpret data	b	1.9	2.7	2.5
Ability to design systems and components as needed	c	1.7	2.8	2.3
Ability to work well in diverse or multidisciplinary teams	d	1.8	3.5	4.0
Leadership abilities	d	1.8	3.1	3.5
Ability to work independently	e	2.5	3.5	4.2
Self confidence	e	2.1	3.5	3.4
Problem-solving skills	e	1.8	3.1	3.0
Creative thinking	e	2.4	3.4	3.8
Critical judgment	e	2.0	3.3	3.4
Appreciation of professional behavior	f	3.1	3.9	3.9
Appreciation of ethical behavior in engineering	f	2.7	3.9	4.0
Writing skills	g	2.4	4.2	4.1
Speaking skills	g	1.5	2.6	2.3
Awareness of the political and societal context of eng.	h	2.9	3.7	4.0
Ability to learn on your own	i	2.3	3.5	3.9
Understanding of contemporary issues in science and tech.	j	2.7	3.6	3.6
Computing skills	k	1.7	2.7	2.9

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