Continuous Improvement of the Assessment and Measurement Process for Engineering Education

William E. Simon, Terrence L. Chambers

Department of Mechanical Engineering
University of Louisiana at Lafayette

Abstract

Assessment and measurement techniques for compliance with ABET EC-2000 criteria must be developed and implemented early in the accreditation cycle to facilitate adequate engineering program reporting, i.e., sufficient quantity and quality of the "correct" type of data for verification of desired program outcomes. Many engineering departments have for years been "doing it the old way," i.e., essentially conducting informal qualitative assessments by talking to employers, alumni, students and others interacting with the educational process. However, this data was for the most part not properly documented, and often the instruments of measurement were not clearly defined and certainly not used in an optimal fashion.

To properly satisfy EC-2000 criteria, an indepth review of each program's mission and program educational objectives is required at the outset, which then results in a set of program outcomes selected to measure the viability of the program. Once program outcomes are defined, an assessment and measurements process can be developed to measure the degree of achievement of these outcomes. Beginning with the constituents of a program (clients, supporters, and other individuals or organizations interacting with the department administering the program) and their relationship to its academic "implementers," and operating within university policies and constraints, the process provides a means for verification of the desired outcomes, and, properly integrated with the decision-making process of the organization, serves as a measure of the milestones of achievement critical to achieving the desired outcomes. An optimal set of assessment tools for a given program is selected; these instruments then facilitate the gathering of data on a periodic basis, after which this data is recycled into the assessment process. A triple-feedback mechanism provides for continuous monitoring of progress toward predetermined programmatic milestones with checks at regular intervals so that measurement instruments can be kept up-to-date, and desired program outcomes and program objectives can be revised or modified if needed. Based on these periodic re-assessments, implementation procedures and the curriculum proper can be changed as needed to keep program outcomes relevant to the mission of the organization and its program objectives, and to assure that the outcomes are successfully achieved by all students who successfully complete the program.

This paper, then, presents a process for continuous improvement and describes progress made over a period of one year in assessment and measurement of the Mechanical Engineering program at the University of Louisiana at Lafayette.

Introduction

In a previous paper[1], a model of an assessment and measurement process for compliance with ABET EC-2000 criteria was presented. Such a process must necessarily begin with a thorough understanding of constituent requirements/desires and program constraints, which bear directly on the mission statement of the program. From the mission statement, program objectives can be defined, and finally, desired program outcomes can be developed to achieve the program objectives. Such a process is depicted in the diagram of Figure 1.

In Table 1 is shown a typical set of desired program outcomes derived through the above process. The fourteen chosen outcomes are a composite of program requirements from EC-2000 Criteria 1-4[2] and additional desired outcomes suited to the needs of this particular program. It should be noted that while all Mechanical Engineering programs must satisfy Criteria 1-4, additional self-imposed criteria may be adopted for any given program. Once the desired outcomes are established, a process must then be developed to assure their successful achievement through adequate assessment and measurement techniques. What follows is a description of such a process, as well as a long-term process for continuous improvement.

Selection of Measurement Instruments

Tools of measurement must be carefully selected to assure that all desired outcomes can be properly measured. This selection process and the correlation of measurement instruments to detailed aspects of the curriculum proper is the subject of another paper[3]; however, these measurement instruments must be synchronized to the desired program outcomes, since typically only a limited set of outcomes can be addressed by any one instrument. The synchronization process helps to resolve the question of whether or not certain measurement instruments can successfully reach into individual units of each course in the curriculum for thorough assessment of outcomes achievement. If this cannot be done, then other means of gathering data must be used to verify that all outcomes are being achieved by all students who successfully complete the program.

The selected instruments must be chosen judiciously, used regularly, and not expected to provide data outside the scope of the assessment parameter(s) for which each was selected. A typical set of measurement instruments is shown in Table 2.

Triple-Feedback Process for Continuous Improvement

Figure 2 depicts an integrated verification process for (1) assuring correct applicability and usage of the selected measurement instruments (MIs); (2) periodic re-assessment of the desired program outcomes (DPOs); and (3) long-term evaluation of program objectives (POs). Once the measurement instruments are in place for a given set of desired outcomes, the verification process is put through the test through a measurement and analysis process which assures the measurement of every outcome by at least one measurement instrument.

After the first round of data is gathered using the chosen measurement instruments, the data is assembled by program outcome, analyzed, and documented. At this point the adequacy of the measurement instruments, or their inadequacy as the case may be, is determined, and a decision is made on whether or not to discontinue certain measurements and to replace them with other measurement techniques.

On a longer time cycle, the desired program outcomes are re-assessed, and another decision is made on whether or not to modify or re-define them. Again, over an even longer cycle, an evaluation of program objectives is conducted for assurance of continuing compatibility with the mission statement of the organization. These objectives can at this point be modified, or this step can be bypassed; but the process insures that they are examined on a regular long-term basis.

Results

For the set of desired outcomes and measurement instruments of Tables 1 and 2, the process of gathering assessment data was begun approximately one year ago by the Mechanical Engineering Department of the University of Louisiana at Lafayette. A designated office with computer, filing system and room for faculty to meet and discuss aspects of the data analysis effort, was set up. In the "Assessment and Measurements" Office, a large notebook is kept for each of the 14 outcomes, which contains all information and documentation pertaining to the measurement of that outcome. For example, FE (Fundamentals of Engineering) exam results and completed Senior Exit Interview forms are found here, together with periodic internal memoranda written by faculty in charge of that outcome. Mechanically and physically, this system is adequate.

However, shortly after beginning to implement the new process, complaints by faculty in charge of certain outcomes led to the exercise of the first (inner) loop, wherein the measurement instruments had to be reassessed. It was found that many of the chosen instruments, while providing meaningful quantitative input for improving the program, were inadequate for measuring specific desired outcomes. For example, the standard course/instructor scantron evaluations used by the university, while providing student opinions on each course and instructor, did not contribute significantly to the assessment of *any* outcome, although it was at first believed that it could potentially contribute to all. The same was true for inputs from the

Industrial Advisory Board. To solve this dilemma of vagueness of clear ability to evaluate each outcome, it was decided by the faculty to administer, within each Mechanical Engineering course, focused questions to test outcomes relevant to every course, or to dissect exam grades, lab reports, etc. so that these questions could be answered. For example, in the Senior Seminar class questions were to be asked, and results graded, to address outcomes 9 through 13 (see Table 1). Although it was decided to do this for each course, it soon became apparent that the process was so cumbersome that a better way should be developed.

In summary, a re-assessment of the measurements resulted in the decision to go to a comprehensive, FE-type exam to seniors using the Senior Seminar class to administer the test. An orientation is given students at the beginning of the semester, and they are provided with "study books" containing formulas, conversion factors and practice problems. Students study on their own throughout the semester, and a practice test is given several weeks before the actual test. Faculty provide questions to a designated faculty member based on material covered in their individual courses. The faculty member in charge of the test integrates the questions into a comprehensive exam which is designed to provide into all desired outcomes. Students are told that to pass the course and graduate, they must pass this exam. Should they not pass it the first time, they are given additional opportunity to do so, outside of class, before the end of the semester.

Other instruments, such as Senior exit interviews, are retained, but are used more on a qualitative level to provide inputs for continuous improvement. Still other instruments originally identified as potentially useful, were dropped in the first re-assessment. Examples are "Inputs from Other Institutions" (this instrument arose from Mechanical Engineering Department Head meetings from which useful data was obtained to gauge this program against other similar programs); and "ABET Evaluators" (improving the program the program after each ABET visit based on comments from the visitors).

Conclusion

Although the triple-feedback process for continuous improvement is still relatively new and has not yet been thoroughly exercised in all its feedback loops, it has already provided valuable inputs to the assessment process in pointing up ways in which the system of measurement instruments had to be modified. With faculty buy-in and a strong Industrial Advisory Board to provide oversight and calibration for program linkage to the outside engineering world, it is anticipated that the new process will succeed in demonstrating the achievement of desired program outcomes, assuring a viable program for years to come, accommodating to changing constituent needs, and amenable to verifiable means of continuous improvement.

References

1. "Assessment and Measurement Innovations for Continuous Improvement in Engineering Education," by William E. Simon and T. L. Chambers, *2002 ASEE Gulf-Southwest Annual Conference*, Paper IIC2, Lafayette, LA, March 20-22, 2002.

2. "Criteria for Accrediting Programs in Engineering in the United States," ABET Criteria EC-2000, Engineering Accreditation Commission, Accreditation Board for Engineering and Technology, Inc., Baltimore, MD 21202, December 26, 2000.

3. "Curricular Analysis in the Assessment of Program Outcomes for ABET Criteria EC-2000," by William E. Simon and T. L. Chambers, *2002 ASEE Gulf-Southwest Annual Conference*, Paper IIC3, Lafayette, LA, March 20-22, 2002.

WILLIAM E. SIMON
Dr. Simon currently serves as Professor and Head of the Mechanical Engineering Department at the University of Louisiana at Lafayette. His research interests are in the aerospace and thermal science areas, including fuel cells, conventional and state-of-the art heat and mass transfer, thermodynamics, multidiscipline advanced development technology management, and large project management. Dr. Simon is a registered engineer in the state of Louisiana.

TERRENCE L. CHAMBERS
Dr. Chambers currently serves as an Assistant Professor of Mechanical Engineering at the University of Louisiana at Lafayette. His research interests include engineering design and optimization, artificial intelligence, genetic algorithms and genetic programming, engineering software development, and numeric and symbolic solutions to engineering problems. Dr. Chambers is a registered Professional Engineer in Louisiana.

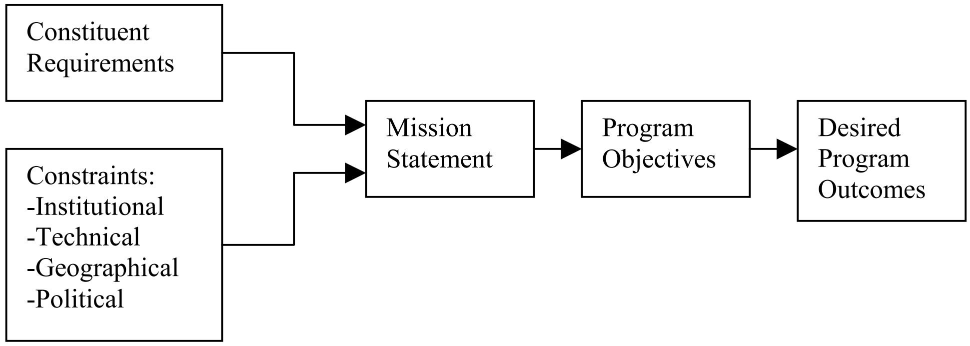

Figure 1. Development Process for Desired Program Outcomes

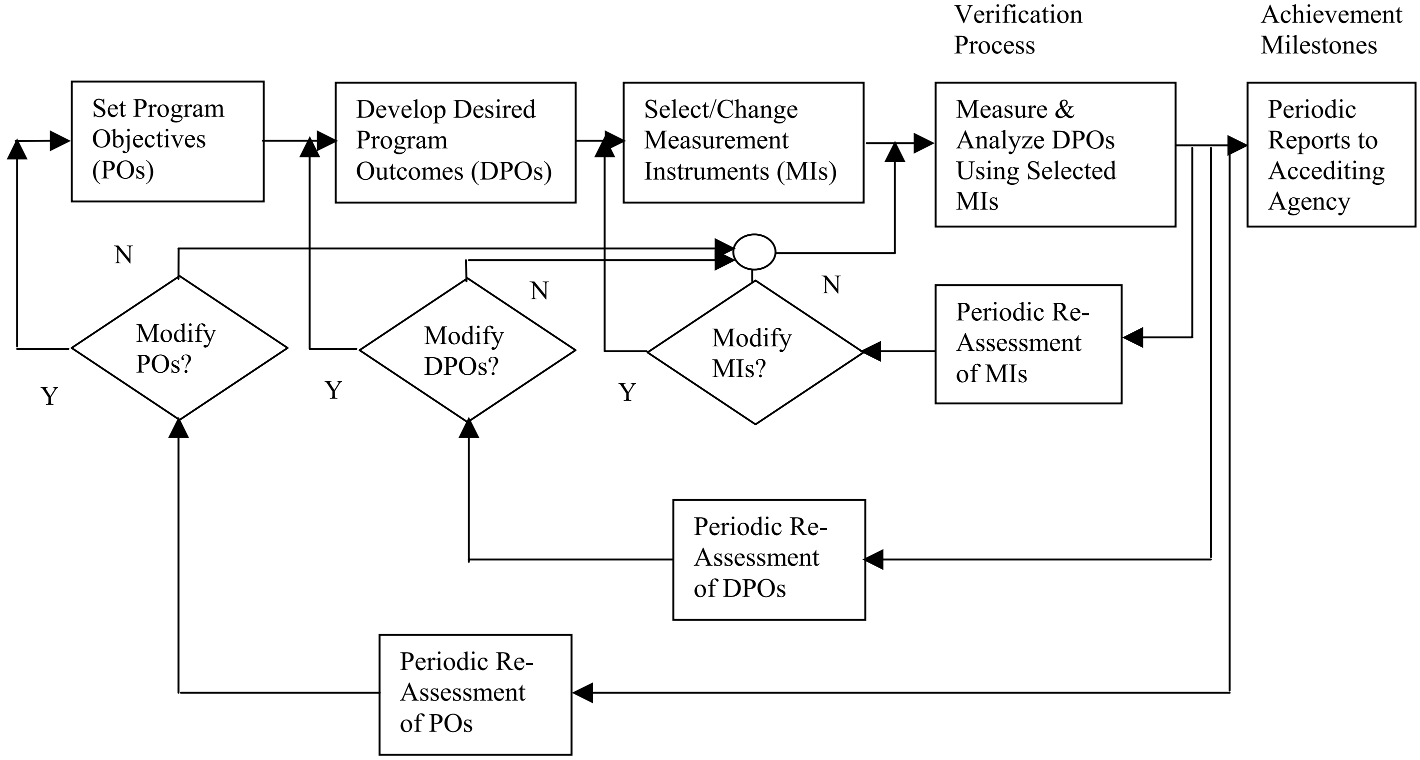

Figure 2. Process for Insuring Continuous Improvement in Verification of Desired Program Outcomes

Table 1. Typical Set of Desired Program Outcomes

1. An ability to apply knowledge of mathematics, through multivariate calculus and differential equations;
2. a familiarity with statistics and linear algebra;
3. an ability to apply scientific knowledge, including chemistry and physics, with depth in physics;
4. an ability to apply knowledge of fundamental engineering principles;
5. an ability to design and conduct experiments, and to collect and analyze data using modern analytical, computational, and experimental practices;
6. an ability to design a system, component, or process to meet desired needs;
7. an ability to function in multidisciplinary teams;
8. an ability to identify, formulate and solve mechanical engineering problems from both the thermal and mechanical systems areas;
9. an understanding of professional and ethical responsibility;
10. an ability to communicate effectively, both orally and in written communications;
11. the broad education necessary to understand the impact of engineering solutions in a global and societal context;
12. a recognition of the need for, and an ability to engage in, life-long learning;
13. a knowledge of contemporary issues;
14. an ability to use and apply modern engineering skills, techniques, and computational tools.

Table 2. Synchronization of Program Outcomes with Selected Measurement Instruments

UL Lafayette MCHE Program Desired Outcomes	Course Instruments	Alumni Questionnaire	Sr. Exit Interviews	FE Exam Results	IAB Inputs	Student Advisory Committee	Course/Instructor Evaluations	ABET Evaluators	Inputs from Other Institutions
An ability to apply knowledge of mathematics, through multivariate calculus and differential equations	✓		✓		✓	✓		✓	
A familiarity with statistics and linear algebra	✓		✓		✓	✓		✓	
An ability to apply scientific knowledge, including chemistry and physics with depth in physics	✓		✓		✓	✓		✓	
An ability to apply knowledge of fundamental engineering principles	✓		✓	✓	✓	✓		✓	
An ability to design and conduct experiments, and to collect and analyze data using modern analytical, computational, and experimental practices	✓		✓		✓	✓		✓	
An ability to design a system, component, or process to meet desired needs	✓		✓		✓	✓		✓	✓
An ability to function in multi-disciplinary teams	✓		✓		✓	✓		✓	✓
An ability to identify, formulate, and solve mechanical engineering problems from both the thermal and mechanical systems area	✓		✓	✓	✓	✓		✓	✓
An understanding of professional and ethical responsibility	✓		✓		✓	✓		✓	
An ability to communicate effectively	✓	✓	✓		✓	✓	✓	✓	✓
The broad education necessary to understand the impact of engineering solutions in a global and societal context	✓	✓	✓		✓	✓		✓	
A recognition of the need for, and an ability to engage in life-long learning	✓	✓	✓		✓	✓	✓	✓	✓
A knowledge of contemporary issues	✓		✓		✓	✓		✓	
An ability to use and apply modern engineering skills, techniques, and computational tools	✓		✓		✓	✓		✓	

✓ Indicates that input is regularly received for this outcome