Complete ABET Program Assessment (CAPA) for a New Engineering Program

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Abstract

This is the final paper in a series documenting the tools and methods developed to implement systems and a culture for continuous improvement of a new engineering program. The Citadel School of Engineering initiated a Bachelor's of Science in Mechanical Engineering program in the fall of 2014 which became accredited in 2017. The mechanical engineering courses were prepared using the ABET engineering accreditation criteria in mind, and the new team of mechanical engineering faculty worked on collection, assessment and evaluation of the program in order to provide a quality educational experience for students. This paper will describe the highest level tools, techniques, and best practices developed during this process. It will show the continuity between the lower level course assessments and how these courses provided input into the higher level program assessment. Additionally, measures are illustrated to show how they provided information to the assessment of student outcomes and the overall ABET program assessment. The methodologies allow the faculty to assess, analyze, and suggest improvements that can be implemented in future years. These tools are currently being used by the ME faculty to identify areas in need of improvement in all ME courses as well as the program.

Keywords

ABET accreditation, program assessment, new engineering program

ABET Accreditation

The Accreditation Board for Engineering and Technology (ABET) is a nonprofit accrediting agency for academic programs in applied and natural science, computing, engineering and engineering technology which provides assurance that a college or university program meets the profession's high standards in preparing students[1]. Accreditation is voluntary, and since 1932, over 3,800 programs at more than 770 colleges and universities in 31 countries have earned ABET accreditation. Over the past several years, about 85,000 students graduated from ABET-accredited programs.

ABET accredits programs, not institutions, providing focused engineering accreditation for post-secondary programs within degree-granting institutions already recognized by national or regional institutional accreditation agencies. This specialized accreditation for engineering is a guarantee that the engineering students who will eventually serve the public have a solid education and are capable of leading the way in innovation, emerging technologies, and anticipating the welfare and safety of the public. ABET accreditation is a benefit for students, programs and institutions, industry, government, and the public.

The ABET accreditation review process is an intensive team effort, but it demonstrates a program's commitment to delivering quality education. The process yields data and insights that can be used to deliver the best educational experience and prepare students. Students can be confident in their education knowing that ABET is the trusted standard worldwide. ABET accreditors know workforce needs and review academic programs to ensure they provide the skills graduates need to succeed. The ABET review process, once cultivated and used, can assist the faculty team to document, analyze, and plan for improvement[2].

The New Mechanical Engineering Program at The Citadel

The Citadel School of Engineering has a proud record of significant contributions at The Citadel since its inception in 1842[3]. The Mechanical Engineering Program was added in 2014, joining the Civil and Environmental Engineering Department and the Electrical and Computer Engineering Department. The first mechanical engineering courses (MECH) were offered in the fall of 2014. The School of Engineering applied for accreditation of the new Mechanical Engineering Program as soon as the first mechanical engineering students graduated in May 2016.

The new Mechanical Engineering Program is available to the cadet population as well as to the evening students transferring from partnering community and technical colleges (2+2 programs). The full-time evening Mechanical Engineering program mirrors the current full-time evening 2+2 programs in Civil and Electrical Engineering.

The new program courses were developed using the ABET engineering accreditation criteria, ensuring course objectives were nested in the student outcomes and had embedded indicators as part of the assessment plan. The new team of mechanical engineering faculty worked on collection, assessment and evaluation of the courses in order to provide a quality educational experience for students. Early improvement and goal-oriented changes will also keep the program viable in the long term.

The Mechanical Engineering Program hosted the initial ABET accreditation visit in 2016. The program was only two years old, and the first organized assessment process began in fall 2014 with course assessments and the development of a list of embedded indicators tied to student outcomes for each course. Since many of the demonstrations of student outcomes occur within senior level courses, the first complete program assessment occurred with the 2015-2016 academic year. The annual program assessment process was developed over the first year.

The new Mechanical Engineering courses were already thoroughly described and approved by the South Carolina Commission on Higher Education. Each one has a list of course outcomes which are being used to evaluate the courses. Once a course is taught, it is critical that each faculty member reviews and critiques the assessment instruments and assessment indicators used to evaluate the course. This ensures the validity of not only the course material, but the evaluation material as well. A reasonable and important theme is to demonstrate that no matter how good the courses or program is, the faculty members are prepared to make improvements[4].

The course evaluation material will be archived and used in the annual program evaluation process and for future ABET accreditation.

Program Level Assessment

A major portion of the overall program assessment is a compilation of the program individual student outcomes[5]. The mechanical engineering program uses the standard ABET student outcomes (a) through (k), reflecting the skills and attributes that all Mechanical Engineering students are expected to possess at the time of graduation. The program individual student outcomes are based on documentation collected during the annual assessment process and represent a combination of direct and indirect measures. Some examples of credible data which can be used as measures of outcome achievement are provided, in order of priority from best to worst, as follows:

a. Direct measures: Performance of student work (embedded indicators), Fundamentals of Engineering Exam results.
b. Indirect Measures: Survey data
c. Curriculum Measures: Completion of specific curriculum courses

The specific courses that provide the embedded indicators were selected from the course-outcome matrix[5] which indicates how well the course objectives contribute to accomplishment of a given outcome (its contribution to each student outcome). The course-outcome matrix allows a program director to see which courses are contributing most toward each outcome, which in turn provides guidance for where the assessment of student performance should occur.

For each outcome the relevant data are identified. Tables were developed that establish quantifiable criteria in the form of rubrics that are systematically applied annually to assess Student Outcome Embedded Indicators, FE Exam results, Curriculum Measures, and Overall Student Outcomes. The current department standard is indicated on each Student Outcome Table.

After data from these multiple assessment methods is assembled in a single table for each of the 11 Student Outcomes, an assessment of each measure (direct, indirect, and curriculum) is given based on appropriate rubric thresholds developed by the program faculty. Each year, results are analyzed, and a final score for that year is determined for each student outcome. The historical average is also recorded based on a running average over the previous five years if data is available.

Course Level Assessment

Detailed in a previous work[6], a thorough assessment tool for ABET Course Assessment, A.C.A., was used for all courses. It consists of four documents:

a. Grades Approval Form: Documents student incoming and outgoing average GPA for the semester. It also contains information about final examination scores and final grades.

There is a table containing scores for different problems or sections which contains historical data and comments.

b. Course Assessment Data: Links course outcomes with ABET outcomes. The instructor or program director subjectively rates how strongly the course outcomes support the ABET outcomes using the Likert scale from 1 - strongly disagree to 5 - strongly agree. At The Citadel these values come from the ABET course description. At the end of semester the instructor evaluates the values, and if they do not match or are not close a change to the course syllabus and ABET description may be suggested.
c. Faculty and Students Feedback: Contains students course evaluation results and explores students' course evaluations for trends. The responses are divided into sections related to general course questions, instructor evaluation and course objectives assessment.
d. Course Assessment Report: Summarizes and discusses the outcomes of the prior documents, and compares the results to outcomes of previous offerings. It lists course objectives, detailed course content and specifies what topics support what objectives.

Charts with results are presented in the reports together with evaluation of classrooms, laboratories, physical models, textbooks; and proposed changes to catalog description, course outcomes, lessons, laboratories, grading. Appendices will contain historical data comparison and any other supporting documents like narrative feedback from students' course evaluations.

At the completion of the semester, each faculty member develops a course assessment report with embedded indicator results, described in previous papers[6,7]. The report summarizes assessment of each course goal, documents course description and current common course goals, lists equipment required and condition of equipment, itemizes actions taken for improvement based on the previous year's report, and lists improvement items for next year.

Course Level Embedded Indicator Assessment

Each course outcome is evaluated by using embedded indicators which consist of selected graded events that are contained within the course. Each embedded indicator is described and the average grade, the standard deviation of the individual grades and the possible number of points possible for the graded event are recorded. The data for each embedded indicator is then entered into the appropriate course outcome column. Once all data is entered into the spreadsheet, it automatically computes the average and standard deviation for each course outcome. Details and an example of this Tool for Evaluating Course Objectives (TECO) have been previously documented[7].

All graded work: homework, projects, quizzes, and tests with separated questions, is placed in a matrix allowing an immediate course outcomes assessment and possible changes of future assignments in order to add more embedded indicators where needed, review 'muddy points' with students, and work on 'weak spots' of the course.

Embedded indicators, to which all students are exposed, are used as an assessment tool and specifically measure a collectively determined course goal at an appropriate level of performance. Tools are established prior to the student activity, and structured in a manner to take advantage of homework, test questions and projects already in use for the course.

Prior to teaching a course faculty members identify tools that will be used to measure each course goal. Each course goal must be measured at least once for each class. Throughout the semester students are assessed using designated tools. If the average grade on a tool is 75% or higher, then it is determined students have met the requirement of that particular tool, and therefore, the corresponding course goal.

Continuous Improvement Plan and Action

Currently, the annual program assessment is the primary vehicle for proposing changes to the Mechanical Engineering program. The program assessment, typically presented to the Dean, the faculty and the Advisory Board culminates with a series of recommended actions for the coming year. Similarly, the program assessment begins with the status of the recommendations from the previous year, closing the loop and ensuring that the actions are not forgotten. The recommendations are based on the assessment data provided in the body of the program assessment which include criterion 2 and 3 data collections, as well as an assessment of faculty, teaching, budget, facilities, students, and constituencies.

The faculty is small and groups all committee type actions under the weekly department meeting. The faculty have impromptu meetings when something cannot wait until the next weekly meeting. Much of the assessment that drives departmental change is the result of the departmental meetings. For major issues, individual faculty may be asked to study the issue and make a recommendation that is decided by a vote of the faculty.

Other information comes from students, alumni and industry partners. The department chair meets with students on a semester basis and seeks their input. Students are often surveyed on specific issues or on more general topics. The department has been involved in hosting the local American Society of Mechanical Engineers (ASME) branch meetings and presenting recent developments in the ME program at The Citadel. The ME advisory board is being modified to include more local engineering firms and meets twice annually. Each fall meeting results in a report to which the department chair provides a response and considers changes to the program.

Departmental improvements include both process and program type improvements. Process improvements are generally more indirect due to the fact that these types of advancements in the department's assessment process are focused on collecting meaningful data, instituting formalized feedback loops, and establishing linkages with educational objectives, all of which support the ideal of more analytically driven decision making for continuous improvement.

Program improvements are actions that have a more direct impact on students, typically involving curriculum changes, course modifications, and other similar measures focused on enhancing student development and enriching the department learning environment. Numerous other small-scale actions related to annual course improvements, department committee action plans, embedded indicator implementation, and program outcome analysis were also conducted in support of the incremental steps taken through the department's comprehensive program assessment process to improve the program

Improvements are stratified into three categories based on significance to the program to help with documentation and tracking. Appropriate documentation increases as the category increases. The most important element for assessment of course goals are alignment and evidence produced from embedded indicators. The department has adopted at least two direct measures for each student outcome, which is a requirement of Southern Association of Colleges and Schools accreditation, and at least three embedded indicators for each outcome. Additionally, the faculty wanted and provided a more consistent means for grading embedded indicators across different sections taught by different faculty.

Example Actions to Improve the Courses

From the course assessment process there are a number of recommendations for changes in a course that were approved or not approved by the faculty team. Those recommended changes are the first thing that is discussed in the next course assessment prior to entertaining any other proposed changes. The recommended changes result in changes in course descriptions and instruction.

The course description changes noted in the previous academic year were implemented in the Course Catalog Issue, 2014-2015 and are satisfied with the current descriptions. Faculty are currently reviewing courses taught for the first time and annually review all course descriptions. After teaching all courses at least once, the faculty must reexamine all the embedded indicators and ensure they map to the student outcomes and fully demonstrate the designated outcome.

The one suggested course sequence change that was discussed early in the program development was the sequencing of Mechanical System Design, a senior level course. Much of the information in this course would be used concurrently with Senior Design 1. Since these were senior level courses, none of the faculty had taught either course. Senior Design 1 needed to have the design process and tools covered in Mechanical Systems Design as a prerequisite rather than a co-requisite. A “just in time” instructional approach for the material to be implemented into Senior Design could work with the initial small enrollment of students, but not in future years where more students and project advisors may be at different stages of their senior design projects. Mechanical Systems Design was rescheduled to be taught second semester junior year, where all juniors would experience design methodology and tools before starting their senior design.

Example Actions to Improve the Program

The ME Department identified planned improvements to the program as a result of the systematic assessment of student outcomes. With full implementation of the current assessment process, the ME Department initiated annual systematic improvements for each of the 11 Student Outcomes. Both of the direct measures are assessed and systematic improvement actions are developed, executed, and assessed based on collected data. Summaries of the recommendations over the last academic year are also collected. These tables are organized by Student Outcomes and placed in reverse chronological order (current year on top followed by previous years). The general area of improvement is identified in the table first (i.e. Student Outcome Embedded Indicator, FE Exam, curriculum…) followed by a description of the improvement plan, which

was developed based on the data. A brief description of how the plan was implemented, along with an annual assessment of progress concludes the information provided. From information presented in this manner, it is easy to track progress within a specific improvement area and illustrates where needs for reassessment of results occur when initial attempts to make improvement fall short. Table 1 below is an example of the Continuous Improvement Plan for Student Outcome 1.

Table 1 Summary of Student Outcome Improvements for 20xx-20xy AY–Student Outcome 1

20xx-20xy **Student Outcome 1: Apply knowledge of mathematics, science and engineering. (Rubric Score 4)**				
	Embedded Indicator	**Embedded Indicator**	**FE Exam**	**Curriculum**
Improvements Identified based on the assessment 20xx-20xy	MECH 311, CO3: Spend additional time / problem on differential fluid analysis.	MECH 350, CO1: Include review of Laplace transform math.	FE Review Session to include Probability and Statistics	Conduct Prerequisite review of all math courses and specific engineering courses.
Implementation of Improvements 20xy-20xz	MECH 311: To meet the long-term goal, the fundamentals of differential fluid analysis will be emphasized more with less time spent on various applications.	MECH 350, CO1: Include an additional lesson on modeling of physical systems using Laplace transforms and remove the lesson on partial fraction expansion.	Separate session included in overall review with assigned HW.	Ensure math alignment of engineering course material.
Current Actions	**In Progress**	**In Progress**	**In Progress**	**In Progress**
Previous Actions	**NA**	Provided Math Dept with engineering problems using Laplace to teach math in context and use examples.	Slight improvement in FE math score, but based on a small population.	**NA**

A table for each Continuous Improvement Plan for each Student Outcome was developed to assist in the overall program assessment.

Conclusions

The CAPA provides a detailed tool for program assessment and continuous improvement across the entire new Mechanical Engineering program. It provides a common basis to document actions for all program courses and maps to the overall program assessment. Instructors through program director observed an increase in course visibility, better and more efficient course planning, better course assessments and evaluations, and reductions in the time required to perform annual program assessments.

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