ABET Program Assessment (A.P.A) for a New Engineering Program

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Abstract

This is a continuation of a series of papers written to document the tools and methods developed to ultimately assist in 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 2014. The School of Engineering has two ABET accredited programs (Civil and Electrical) and applied for accreditation of the new Mechanical program when the first students graduated in 2016. The initial ABET visit was scheduled for the fall 2016. The new program courses have been prepared using the ABET engineering accreditation criteria, and the new team of mechanical engineering faculty has worked on collection, assessment and evaluation of the program in order to provide a quality educational experience for students. This paper will describe the tools, techniques, and best practices developed during this process. It will show the connection between the course assessments and how they provided input into the program assessment. Additionally, other direct and indirect measures will be illustrated to show how they provide a more thorough assessment of student outcomes and the overall ABET program assessment. The tools and procedures will allow the ME faculty to assess, analyze and suggest improvements that can be implemented in the future offerings. These tools are currently being used by the ME faculty to identify areas in need of improvement in all ME courses. The authors hope that this assessment process will provide a better, unified, consistent, efficient and transparent evaluation and reporting across all courses in the new program.

Keywords

ABET accreditation, program assessment, new engineering program

ABET Accreditation

ABET is a non-profit and non-governmental accrediting agency for academic programs in the disciplines of applied science, computing, engineering, and engineering technology.[1] ABET is a recognized accreditor in the United States by the Council for Higher Education Accreditation. ABET accreditation provides assurance that a college or university program meets the quality standards established by the profession for which the program prepares its students. To date, ABET has accredited over 3,400 applied science, computing, engineering, and engineering technology programs at nearly 700 colleges and universities in 28 countries worldwide.

The ABET accreditation gives an assurance that the professionals that serve the population have a solid educational foundation and are capable of leading the way in innovation, emerging technologies, and in anticipating the welfare and safety needs of the public. Thus the accreditation impacts students, programs and institutions, businesses, industry, government and the public.

The ABET accreditation is a process where educational programs or institutions are reviewed to determine if they meet certain standards of quality. The accreditation is not a ranking system but an assurance that a program or institution meets established quality standards. The ABET engineering accreditation criteria cover all aspects of program evaluation, from high level institutional program educational objectives down to individual program outcomes, including evaluation of a program's continuous improvement processes.[2]

- Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. Program educational objectives are based on the needs of the program's constituencies.
- Student Outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program. Student outcomes should be defined in order for faculty to have a common understanding of the expectations for student learning and to achieve consistency across the curriculum, as measured by performance indicators. Performance indicators represent the knowledge, skills, attitudes or behavior students should be able to demonstrate by the time of graduation that indicate competence related to the outcome.
- Assessment is one or more processes that identify, collect, and prepare data to evaluate the attainment of student outcomes and program educational objectives. Effective assessment uses relevant direct, indirect, quantitative, and qualitative measures as appropriate to the outcome or objective being measured. Appropriate sampling methods may be used as part of an assessment process.
- Understanding the alignment between educational practices and strategies promotes efficient and effective assessment practices. This can be accomplished by mapping educational strategies (which could include co-curricular activities) to learning outcomes.
- Evaluation is one or more processes for interpreting the data and evidence accumulated through assessment processes. Evaluation determines the extent to which student outcomes and program educational objectives are being attained. Evaluation results in decisions and actions regarding program improvement.

The New Mechanical Engineering Program at The Citadel

The Citadel School of Engineering has had a proud record of significant contributions at The Citadel since its inception in 1842.[3] The Civil and Environmental Engineering Department was established in 1912 and became accredited in 1936. The Electrical and Computer Engineering Department was established in 1941 and became accredited in 1976. The Mechanical Engineering Program was added in 2014 with the first mechanical engineering courses (MECH) offered in the fall. The School of Engineering applied for accreditation of the new Mechanical program as soon as the first mechanical engineering students graduated in May 2016.

The new Mechanical Engineering Program of Study offers focused tracks in Power and Energy, Manufacturing, Aeronautical Systems, Materials (Composites), and Mechatronics. It 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 have been prepared using the ABET engineering accreditation criteria, and the new team of mechanical engineering faculty is working on collection, assessment and evaluation of the courses in order to provide a quality educational experience for students. The authors believe that a transparent, well-understood process of continuous data collection and course assessment and evaluation is crucial for the success of the new program. Also, early improvement and goal-oriented changes will keep the program viable in the long term.
The new mechanical engineering courses are 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[2]. The course evaluation materials will be archived and used in the program evaluation process for the future ABET accreditation.

Outcome Linkage and Mapping

Defining linkages between Student Outcomes and courses taught in the curriculum is a subjective process. In creating linkages, faculty “experts” in subject areas met as Course Content Subcommittees and worked collectively to adopt common course goals, Student Outcomes, and appropriate indicators. Originally established in 2014, the mechanical engineering program maintains Course Content Subcommittees. The subcommittees consist of experts in the subject area and faculty who frequently teach these specific courses.

Tables were developed of the current mapping performed and adopted by department faculty. The matrix is founded upon 11 Student Outcomes identified along the horizontal axis and courses in the curriculum on the vertical axis. These tables map core mechanical engineering classes to student outcomes, which are required by all graduates.

The program outcomes are attained largely through the courses offered in the curriculum. The course – outcome matrix shown in Table 1 was developed where each course in the curriculum was assessed with respect to its contribution to each student outcome. This determination is based on how well the course objectives contribute to accomplishment of a given outcome and review of the student work (course notebooks) that demonstrate accomplishment of course objectives (and naturally program outcomes). The matrix was created to be used as part of the course assessment process and updated as part of the annual assessment. The contribution for courses within the ME program control comes directly from the annual course assessment. The contribution was reviewed and independently verified by the Faculty in Spring 2016. The relative contributions of each course were assessed using a 1 to 5 Likert Scale applied to the following rubric in Table 2.

The matrices in Tables 1 and 2 have several benefits. It 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 might/should occur.

Table 1: Mapping of Courses to Student Outcomes (Mechanical Engineering)

Student Outcomes	an ability to apply knowledge of mathematics, science, and engineering (a)	an ability to design and conduct experiments, as well as to analyze and interpret data (b)	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 (c)	an ability to function on multidisciplinary teams (d)	identify, formulate, and solve engineering problems (e)	an understanding of professional and ethical responsibility (f)	an ability to communicate effectively (g)	the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context (h)	a recognition of the need for, and an ability to engage in life-long learning (i)	a knowledge of contemporary issues (j)	an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (k)
MECH 101	2	2	2	2	3	3	3	3	3	2	2
MECH 102	2	2	3	3	3	2	4	3	3	2	4
MECH 304	5	4	3	2	4	3	3	4	4	3	4
MECH 310	5	4	3	2	5	2	3	3	3	3	3
MECH 311	5	4	3	2	5	2	3	3	3	3	3
MECH 325	4	4	4	3	4	3	4	3	3	2	5
MECH 330	4	5	2	2	3	4	4	2	3	2	4
MECH 340	4	3	4	4	5	5	5	5	5	4	5
MECH 345	5	3	5	4	5	5	5	4	5	3	4
MECH 350	5	4	4	3	5	3	4	4	4	2	5
MECH 415	5	3	2	2	5	2	5	2	4	4	5
MECH 450	5	4	5	4	5	5	5	4	5	3	5
MECH 460	5	3	5	5	5	5	5	5	4	5	3
MECH 481	5	5	5	5	5	5	5	4	4	5	5
MECH 482	5	5	5	5	5	5	5	5	5	5	5
Highest Contribution	5	5	5	5	5	5	5	5	5	5	5

Table 2: Contribution of Course to Student Outcome

1	*No identifiable contribution of course to program outcome*
2	*Marginal contribution; no student work; outcome only covered tangentially by text or instructor*
3	*Some contribution; elements of outcome covered in course; no student work that directly contributes*
4	*Substantial contribution; some examples of student work that directly correlate to outcome; not an explicit course objective*
5	*Very large contribution; many examples of student work that directly contribute; outcome is directly related to a course objective*

Department Process for Annual Evaluation of Outcomes

One of the most important outcomes that is assessed for overall program health are the program individual student outcomes. The mechanical engineering program uses the standard ABET student outcomes (a) through (k), reflecting the skills and attributes all Mechanical Engineering students are expected to know at the time of graduation.

At the completion of the semester, each faculty member develops a course assessment report with embedded indicator results, described in previous papers[4,5]. 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. 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.

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 a tool that will be used to measure all course goals. 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.

The program assessment is based on documentation collected during the annual assessment process and represents 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:

Direct Measures

Performance of student work (embedded indicators). Student performance in an activity—an exam, project, or assignment—that correlates directly to a specific outcome can be quite useful as a direct measure. These are often referred to as embedded indicators because they are already embedded in the program; faculty members are already evaluating the performance, often through a grade; and no new instrument needs to be created. Courses that receive a score of 4 or 5 (relative contribution of course to the program) on a department scoring matrix become the best source for these embedded indicators. The activity could be a test question, a homework assignment, a design problem, a group activity, an essay, or a presentation. It is important that the score on the event or a portion of the event correlates directly to a specific outcome. The ME faculty chose several embedded indicators from the curriculum that best correlate to each student outcome. The faculty assigned to teach the courses are responsible for collecting the embedded indicator data and posting it to the specific Outcomes notebook. Once collected, each data set will be assessed for its ability to demonstrate accomplishment of an outcome. The goal is collection of data for each outcome from one course during the junior and senior years that spreads the annual data collection across the curriculum and faculty while demonstrating accomplishment of the outcome – and thus creating a sustainable process.

A subset 44 of the 80 course embedded indicators are assessed annually by the faculty and used as evidence of obtainment of the 11 student outcomes. In all cases, results from at least three embedded indicators are used for overall evaluation of any specific student outcome. The 44 subset of embedded indicators are referred to as Student Outcome Embedded Indicators (SOEI) and are measured, assessed, and documented annually but at a more rigorous level than course embedded indicators. Faculty teaching the course collectively develop an appropriate tool, determine the time in the course when it will be used, and adopt a common grading rubric that is used to grade the embedded indicator. Example work from three students (best, middle, and worst) for each tool is included along with the grading rubric and an embedded indicator coversheet, which provides an assessment of the student performance. This is then entered into the department documentation system consisting of a hardcopy stored on site and an electronic copy entered in Taskstream. The embedded indicator acts as one of the direct measures used when assessing student outcomes.

Fundamentals of Engineering Exam results. The ME Department uses results from the NCEES Fundamentals of Engineering Exam (FE), which starting with the 2014 academic year is a requirement of graduation that students take the exam. The FE exam is a standardized, nationally normed exam taken by engineering students across the country in a controlled environment. Since the test includes subjects such as mathematics, ethics, statics, fluid dynamics, and chemistry, the results correlate directly to some program outcomes. Where applicable, these data are statistically significant, free of instructor bias, and highly credible. The data are only valid if a large number of the students take the examination. If only a small percentage of a program's students take the FE exam, the credibility of the results is significantly diminished. Therefore, all students must take the exam as a requirement for graduation.

Specific topics are mapped to student outcomes based on relevance. A weighted average for each subject matter is compared to the national average. The weighted average is considered to have met the department standard when it falls within one standard deviation of the comparator. The SOEI and the weighted average of the NCEES Fundamental Exam both constitute direct measure assessment methods for assessing attainment of student outcomes.

Indirect Measures

Survey data. The most common data collected are surveys administered to students, faculty, employers, or alumni that ask questions related to outcomes and objectives. While such data are helpful, they are considered indirect measures. A student's opinion through a survey is not as convincing as the student's performance on a sample engineering problem. However, measuring a student attitude with a survey response may be totally appropriate and sufficient. The ME Department administers annual faculty, employers (if available), and senior exit surveys to gauge the perception of obtainment of student outcomes, as indirect measures. For survey questions where the responses are on a 1–5 Likert scale, the desired minimum standard is 4.0/5.

The Citadel ME program conducts several annual surveys that ask students to assess their own performance with respect to the student outcomes. These include the ME Senior Survey administered each year to seniors, a ME faculty, and an Employer survey administered by the department chair. In the future, graduates at the 1, 4, and 8 year marks will also be asked to complete a survey. Because the department developed the surveys internally, the students and faculty are asked specifically about the ME student's ability to attain each student outcome. Faculty and employers (and graduates in the future) are asked to rate student attainment of outcomes as well as the relative importance of an outcome to The Citadel ME program.

Curriculum Measures

Completion of specific curriculum courses. All students must demonstrate competency in The Citadel curriculum by passing courses or obtaining a C or better in some. This direct measure has additional credibility because the courses are from across the college demonstrating basic life skills and the lifelong learning skills. While course grades are not sufficient, by themselves, to show attainment of an outcome, they can be useful and should be used in conjunction with other measures. Course grades can be particularly applicable for courses outside the program that contribute to an outcome. The Citadel requires 24 semester hours in the general education component that includes humanities, social science or English courses as part of its Core (a mandatory breadth component).

Once performance measures are established and relevant data are collected, results are assembled, analyzed and assessed using program assessment rubrics. The data is divided into direct measures, indirect measures, and curriculum measures. The curriculum measures account for the level that the outcome is covered in the curriculum.

Once the relevant data are identified, the faculty assess the desired performance results that would indicate successful attainment of the outcome. After faculty discussion, the desired result for the embedded indicators was an average of 75%. While 70% is passing, accepting that score as an average would indicate that too many students did not meet the standard. ME plans to migrate to a long term goal of 80% as the standard, but as a new program, ME is establishing itself and an 80% standard initially might be too high as the minimum.

For those survey questions where the response was a 1–5 Likert scale, the desired minimum standard was 4.0/5 for most questions.

Tables were developed that established specific threshold criteria in the form of rubrics that are systematically applied annually for assessment of Curriculum Measures, FE Exam results, Student Outcome Embedded Indicators 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. Results are analyzed, and a final score for that year is determined.

Table 3: 2015-16 performance measures and results for MECH student outcome 1.

	Student Outcome 1: Apply knowledge of mathematics, science and engineering.					
	Direct Measures	Tab	Std	2015-16 Data	Historical Average	Assessment
3.1	MECH 304, Course Objective 2	1	75	96.7	98.4	4
3.2	MECH 311, Course Objective 3	2	75	76.7	76.0	
3.3	MECH 350, Course Objective 1	3	75	89.3	90.5	
3.4	MECH 415, Course Objective 1	4	75	84.9	**	
4.1	Mathematics portion of F.E. exam		0.95	*	**	
4.2	Probability and Statistics portion of F.E. exam		0.95	*	**	
4.3	Electricity and Magnetism on F.E. exam		0.95	*	**	
4.4	Dynamics portion of F.E. exam		0.95	*	**	
4.5	Mechanics of Materials portion of F.E. exam		0.95	*	**	
4.6	Fluid Mechanics portion of F.E. exam		0.95	*	**	
	Indirect Measures		Std	2015-16 Data	Historical Average	
5.1	Question A1. Senior survey		4.0/5	5.0	**	5
5.2	Question B1. Faculty survey		4.0/5	5.0	**	5
5.3	Question B1. Employer Survey		4.0/5	5.0	**	5
	Curriculum Measures		Std	2015-16 Data	Historical Average	
6.1	Completion of: CIVL202/301; MECH 304, 311, 345, 350, 415; ELEC 201, 202		3	4	4	4
6.2	Completion of: MATH 131/132/231/234/335; PHYS 221/222/271/272; CHEM 151/152/161/162		3	4	4	4
	2015-16 Assessment:					**4-**

* Results not available for senior students.
** No historical data, first year of data collection.

Table 3 provides results for 2015-2016 for student outcome 1. As shown for each individual measure, these tables include: the adopted standard, 2015-2016 performance, historical average (if data was available), and Outcomes Notebook index tab for reference to supporting documentation of performance results. The historical average is based on a running average over the previous year if data is available. Future historical averages will be kept on a five year running average. Currently, in all cases, recorded data does not extend past one year since the mechanical engineering program is new. Academic year 2015-2016 was the first year in which a complete program assessment using the current assessment process was administered since all courses were taught during that year. For courses taught in academic year 2014-2015, data was collected and is presented as the historical data. At the time of this paper, there were only freshman and junior courses with two years of course assessment data and senior courses with one year of course assessment data.

Outcome 1 received a score of 4- because all criteria are met and a substantial portion of the curriculum contributes highly to this outcome. However, the (-) is based on no data for the FE exam, which were unavailable during this year. The faculty felt it was better to make a conservative assessment due to this lack of complete data to form a thorough assessment. The faculty will need to closely watch for a trend. The minimum acceptable level for any outcome is 3.0, and the program hopes to attain higher scores in most outcomes.

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

Conclusions

The A.P.A. provides a detailed tool for program assessment across the entire new Mechanical Engineering program, adds ease-of-use and transparency to the evaluation efforts, and produces a concise, useful set of assessment data that will be presented to ABET program evaluators. The authors hope that A.P.A. will provide increased program visibility, more consistent reporting across all courses and indicators in the program, and a greatly improved process of on-going data gathering, analysis, and program evaluation.

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