Systematic Approach to ABET Criterion 4: Continuous Improvement

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The U.S. Coast Guard Academy's (USCGA) Naval Architecture and Marine Engineering (NA&ME) program was last reviewed and granted ABET re-accreditation in 2013. Since then, the program has worked to develop a systematic approach to continuously improve the assessment process and student learning. At its most basic level, the system uses Student Outcomes (SOs), Performance Indicators (PIs) providing resolution to each SO, and "Barometric Assessments" (BAs) in which student performance related to each PI is evaluated.

According to the 2013 USCGA NA&ME Self Study, a committee of permanent faculty would undergo an in-depth, 6-year process during which each SO – in particular its PIs and BAs - would be revisited individually. The process begins with revisiting and revising each SOs PIs. Next, the current PIs associated with that SO would be examined and confirmed, replaced or improved. Finally, the BAs paired with each PI were examined and either confirmed, replaced or improved. A key piece of the examination of the BAs is the role of this committee in suggesting refinements or gross changes to those assessment tools to the instructors of individual courses where the BA is executed. After each SO is visited, it undergoes a one-year trial, and all changes are evaluated and improvements are considered.

The SOs that had proved problematic to measure in the past were first selected for review. To date, ABET Criterion 3 SOs 'a', 'b', and 'k' have been reviewed, while SOs 'g', 'j', and NA&ME SO part 3 have been reviewed and improved are currently under evaluation. Currently, ABET SOs 'c', 'd', and 'i' are under review. This process has proved invaluable at approaching each SO individually rather than attempting to tackle all eleven general SOs and the three parts to the NA&ME specific SO. As this process has proven effective, future work will be modified to likewise revisit all SOs when ABET changes the eleven SOs from 'a' through 'k' to the new seven SOs.

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Abbreviations:

BA	Barometric Assessment
ED##	Engineering Department Student Outcome
EOCR	End-of-Course Review
NA&ME	Naval Architecture and Marine Engineering
NE##	Naval Architecture and Marine Engineering Specific Student Outcome
PI	Performance Indicator
PIAL	Performance Indicator Achievement Level
SO	Student Outcome
USCGA	U.S. Coast Guard Academy

Background

The USCGA's NA&ME program of study has been accredited by ABET since 1973; re-accreditation was awarded in 2013. Re-accreditation is a multi-year process that includes a self-study intended to respond to ABET criteria 1 through 8 (ABET, Inc.). Most criterion give the review team a better idea of the institution itself; criterion 3 and 4 focus specifically on assessment and continuous improvement of the assessment process.

Criterion 3 concerns Student Outcomes (SOs). ABET prescribes eleven SOs for all Engineering programs; the USCGA NA&ME program adds three additional outcomes to this collection (described in the next section). The SOs are intended to prepare graduates to attain the program's educational objectives, a key for success. The interpretation and assessment of SOs will be outlined below.

Criterion 4, Continuous Improvement, is the focus of this paper. During the 2013 NA&ME ABET Self-Study, NA&ME faculty observed that the original local interpretations of the SOs, namely the PIs, had not been revisited since their adoption in 2009. With time and experience behind them, faculty suggested that there was room for improvement with both the PIs and the BAs used to asses those PIs. Therefore, a plan was developed and documented in the 2013 self-study to revisit those PIs and BAs for every SO in order to ensure that they were in proper alignment with how the

USCGA NA&ME program could best use these assessment tools.

This SO review process has become even more relevant as ABET moves toward adopting only seven SOs. It is the intention of the NA&ME faculty to use this same process in order to develop new PIs and BAs to interpret and assess the new SOs.

The paper describes the development of our assessment process, the proposed continuous improvement process, its current implementation and future considerations.

Description of the Historical Assessment Process

The 14 SOs for the USCGA NA&ME Program are taken directly from the ABET (a) – (k) and from the ABET program-specific criteria. This has been the case for many years. Locally, the (a) – (k) outcomes are abbreviated as ED01-ED11, because they are common across the four engineering majors at the USCGA, housed in a "school of engineering" called the Engineering Department. The program-specific outcomes are abbreviated as NE01-NE03, because they are specific to the NA&ME Program. The 14 SOs for the NA&ME Program are shown in Table 1.

Up until 2006, the process was one that assessed the ED01-ED11 and NE01-NE03 outcomes using faculty ratings of the degree to which individual courses covered those topic areas. Such assessment of these 14 outcomes had been in place at the USCGA for many years, and regularly led to many improvements. Typically, assessment of ABET SOs took place piecemeal through the every-semester EOCR process, described later, and all SOs were reviewed for achievement during the Program Reviews held every two years where significant course changes were documented. For wholesale course changes linked with assessment, the Department of Engineering Review documented such changes, staggered every other year from the NA&ME Program Review.

Recent Progression of the Assessment Process

From 2007 to 2009, the NA&ME faculty carried out large-scale evaluation of its processes for the assessment of student achievement outcomes. By 2009, the process used student performance on a combination of specific assignments, projects, and/or examinations called BAs. These BAs served as "barometers" of each cadet's performance in the outcome areas. For each SO, the faculty identified one or more BAs that were judged to be key measures of student achievement of that outcome. The demonstration of each student's achievement of a particular outcome was examined in several program-required courses using several BAs. Each student's level of achievement on each outcome was compared to pre-defined minimum acceptable levels of achievement. Then, the percent of all students who demonstrated acceptable individual achievement was compared to pre-defined overall achievement thresholds for that SO.

Table 1: Student Outcomes for the USCGA NA&ME Program.

ED01 - An ability to apply knowledge of mathematics, science and engineering
ED02 - An ability to design and conduct experiments, as well as to analyze and interpret data
ED03 - 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
ED04 - An ability to function on multidisciplinary teams
ED05 - An ability to identify, formulate, and solve engineering problems
ED06 - An understanding of professional and ethical responsibility
ED07 - An ability to communicate effectively
ED08 - The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
ED09 - A recognition of the need for, and an ability to engage in life-long learning
ED10 - A knowledge of contemporary issues
ED11 - An ability to use techniques, skills, and modern engineering tools necessary for engineering practice
NE01 - An ability to apply probability and statistical methods to naval architecture and marine engineering problems
NE02 - A basic knowledge of fluid mechanics, dynamics, structural mechanics, materials properties, hydrostatics, and energy/propulsion systems in the context of marine vehicles
NE03 - A familiarity with instrumentation appropriate to naval architecture and/or marine engineering

Introduction of Rubrics for Outcomes Assessment

In 2009, all BAs used in the NA&ME Program were conventionally graded assessments such as homework, exam problems, quiz problems, lab reports or design reports. Over the preceding several years, NA&ME faculty realized that BAs of this nature offered too little latitude for faculty to properly assess the full breadth of certain SOs. The faculty were initially focused on improving the assessment of the more broadly defined SOs such as ED06 (An Understanding of Professional

and Ethical Responsibility) and ED09 (A Recognition of the Need for, and an Ability to Engage in Life-Long Learning), but soon realized that assessment all of the SOs, beyond just ED06 and ED09, would be greatly improved by the addition of some assessment rubrics.

Under the existing BA process, if students failed to adequately express their understanding in the BA assignments, the faculty concluded a lack of achievement of the SO. But the faculty also realized that often a SO has significant breadth and depth that manifests itself in a wide variety of situations in the engineering education and design process. The NA&ME faculty surmised that well-developed rubrics might provide more suitable, flexible, and repeatable instruments for measuring student achievement, without the constraints imposed by a single written assignment.

During 2009 and 2010, the decision was made to continue the development of rubrics for the assessment of achievement of certain SOs. It was concluded that "rubric" would be a general term for a tool that provided quantitative/numerical data based on faculty interviews of students, faculty observation of students, student peer assessments, faculty review of homework/exams and the like. A small working group of NA&ME faculty then identified the following relatively broad SOs as highest priority for the addition of rubrics:

ED03 – 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

ED04 –An ability to function on multidisciplinary teams

ED06 – An understanding of professional and ethical responsibility

ED07 – An ability to communicate effectively

ED08 – The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

ED09 – A recognition of the need for, and an ability to engage in life-long learning

Introduction of Performance Indicators for Outcomes Assessment

In parallel, during a 2009 holistic review of the entire NA&ME program by the faculty, it was decided that individual SOs were sometimes too broad to be effectively assessed. As such, the faculty proposed to develop PIs to accompany each SO. PIs are statements describing a competency or skill that each student is expected to attain. It was decided that several PIs would be associated with each SO to provide resolution on the NA&ME Program's interpretation of the meaning of each SO as it applies to the USCGA NA&ME Program. The PIs would allow the relatively general SOs to be broken down into several specific, measureable statements identifying the performance(s) required to meet the SO and would be confirmable through evidence.

During 2010 and 2011, the NA&ME faculty developed several PIs for each SO. The new, program-specific PIs, would now be the actual performance against which students were assessed.

Current State of Outcomes Assessment Process

As above, from 2007-2011, student achievement of each SO was assessed directly based on student performance on one or more BAs, primarily student assignments, exams, quizzes, papers, laboratory reports, design reports, etc. But, from 2011-present, student achievement of SOs has been inferred through the use of PIs, using BAs focused on each PI. These BAs are either student assignments (or pieces of assignments) or faculty-created rubrics, both tailored to individual PIs.

In the end, demonstration of student achievement of a particular PI is examined using a BA in one or more courses. Figure 1 shows a flowchart of the use of BAs to assess student achievement of a PI in a particular course.

As shown in Figure 1, the degree to which a PI has been achieved by individual students in a course is measured with PI Scores. A PI Score is the student's numerical performance on the BA (assignment, exam, quiz, rubric, interview, etc.) in that course. The NA&ME faculty predetermined a PI Score Threshold (currently 70%) to represent the PI Score necessary for satisfactory level of achievement. This singular value of achievement (70%) is currently used for all PIs as a means to pilot the thresholds for BAs and PIs. The lowest level of acceptable competency is 70%, the highest is 100%.

Declaration of the *overall* effectiveness of a given course at producing student achievement of a given PI is then based upon consideration of the PI Scores for all NA&ME students in that course. If the course has students from other majors in it, only the NA&ME student grades are considered for assessment. Faculty defined an Achievement Threshold as the percentage of students (currently 75%) who must have individual PI Scores above the PI Score Threshold. In other words, currently at least three-quarters of students must meet or surpass the PI Score Threshold. Again, a one-size-fits-

all achievement level (75%) has been selected for piloting purposes. The NA&ME Program has plans to slowly adjust this threshold for certain PIs in the future.

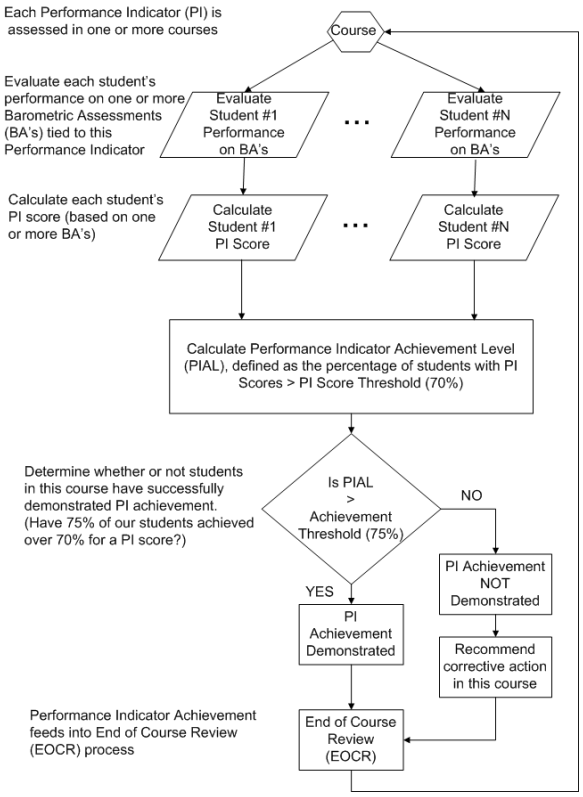

Figure 1: Flowchart of the process for assessing student achievement of a single Performance Indicator in a particular course. Note that each student is assigned an individual Performance Indicator Score and that a minimum proportion of students must exceed a Performance Indicator Score Threshold. The result of this flowchart is a determination of whether students, as a whole, have demonstrated achievement (or not) of a particular PI in this particular course.

As an example of the application of Figure 1, assume that there are 5 NA&ME students in a class. They have PI Scores (based on each student's performance on a particular BA) for a particular PI of 96, 88, 81, 72 and 65, respectively. Four of these students (or 80%) exceed the PI Score Threshold of 70%. Because 80% is above the 75% Achievement Threshold, this course would be declared as successfully producing achievement of this PI among NA&ME students.

At the conclusion of each semester, there is a faculty-executed "End-of-Course Review" (EOCR) that considers all aspects of that offering of each course (Colella, 2002). To institutionalize the SOs assessment process, a section of the EOCR record is now dedicated to documenting student performance in that course on certain PIs. In that section, the details of the BAs and student performance on the BAs during that semester are discussed and PI Scores are compared to the PI Score Threshold. The student PIAL (i.e., the percentage of NA&ME Program students with PI Scores above the PI Score Threshold) is compared to the Achievement Threshold in order to declare achievement (or not) of that PI in that course. Histograms of student PI Scores on the BAs in that course are included. If PI achievement is not attained, then proposed remedial action for future offerings of the course is identified and documented. Course and NA&ME Program improvements from this process also flow from the EOCR to the biannual NA&ME Program and Engineering Department Reviews. Effectively, the flowchart process of Figure 1 is carried out by the faculty at the EOCR meetings.

As above, a particular PI is assessed in one or more courses. The PI is declared to have been successfully demonstrated if the NA&ME students in at least one of the courses have successfully demonstrated that PI. A SO is considered to be successfully demonstrated when all of the PIs for that Outcome have been successfully demonstrated by the NA&ME students. Shown in Figure 2 is the flowchart process by which overall student achievement of a particular SO is inferred by examining the levels of student achievement of all supporting PIs. Appendix A shows the Program's SOs, PIs, and BAs as of 2013.

Continuous Improvement Proposal

The following three-tier strategy was proposed for future continuous improvement of this process.

1. *Refine Performance Indicators and Improve Barometric Assessments:*

Because NA&ME students have performed quite well on the SOs over the past several years, only a modest number of NA&ME program changes have been enacted based solely on the results of BAs. As an effort for foster continuous improvement, the NA&ME Faculty have recently decided to revisit the PIs and BAs for each SO over the next several years. Those that have the highest potential for improvement will be revisited first, with changes enacted on a pilot level for one year, and then fine-tuned at the end of the pilot year. In this way, it can be assured that the PIs and BAs continue to propel the NA&ME Program forward for better educational outcomes.

A tentative schedule, shown in Table 2, has been proposed based on the last few years of assessment of SOs. This schedule to revisit and revise PIs, BAs, and rating of the BAs, to include rubrics, is the result of the relative success of the BAs over the last several years. This is in an effort for continuous improvement to the NA&ME Program and attempting to align the PIs as

closely as possible with overarching goals of the NA&ME Program. The resulting revisions will make many NA&ME Program changes more directly related to BAs, rather than indirectly as many have been to this date.

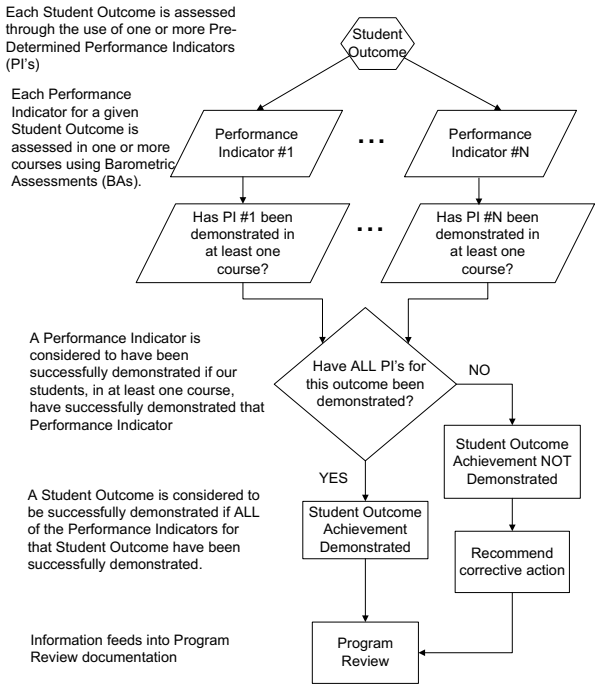

Figure 2: Flowchart of the process for inferring overall student achievement of each Student Outcome by examining the levels of student achievement on all supporting PIs. Note that all supporting PIs must be successfully demonstrated, but that demonstration of a particular PI is only necessary in one course.

2. Add Grading Rubrics:

In the case of some SOs and PIs, the faculty originally noted that the desired outcomes sometimes implied a very broad set of skills; examples would be ED01 and ED05. As such, in those limited cases, the faculty initially used final grades, final exam grades, grades on entire written reports, grades on entire exams, etc. as the BA of student performance. But, since sometimes these grades or assignments do not necessarily capture only the most relevant component for the PI, the NA&ME faculty are currently piloting an initiative to add grading rubrics to go along with those assignments. This initiative will coincide with the PI/BA revisions proposed in Table 2. These grading rubrics will not only improve the normal grading process, but will also allow instructors to provide data from these same assignments that is more directly focused on the spirit of those PIs. This data is expected to provide (within about 2 years) either a confirmation that the students are in fact performing quite well on those PIs, or instead provide an indication that upon more detailed examination that good performance on an entire exam or assignment was masking poor student performance on the subset of skills directly related to the PIs.

Table 2: USCGA NA&ME schedule for future continuous improvement of Performance Indicators and Barometric Assessments as documented in the 2013 NA&ME ABET Self-Study.

Academic Year	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
Revisit and revise Student Outcomes (Performance Indicators, Barometric Assessments, develop rubrics as appropriate)	ED01, ED02, ED11	ED07, ED10, NE03	ED03, ED04, ED09	ED05, ED08, NE01	NE02, ED06	
Evaluate and improve changes.		ED01, ED02, ED11	ED07, ED10, NE03	ED03, ED04, ED09	ED05, ED08, NE01	NE02, ED06

3. Increase Performance Thresholds:

Currently, the PI Score Threshold (individual student) and the PIAL (entire cohort) are 70% and 75%, respectively. Given that the assessment processes for the past several years have seen student performance that nearly always met these thresholds, NA&ME faculty have decided that a slow increase in these values is warranted and will be considered in the revisions outlined in Table 2. The goal is to begin to identify PIs and SOs on which students consistently perform the poorest. NA&ME faculty can then capitalize on these indicators as the foundation for future NA&ME Program and course improvements.

Continuous Improvement Implementation

A committee of four permanent faculty within the NA&ME program was developed to implement the process outlined previously, focusing primarily on refining the PIs and improving BAs.

In January 2014, the committee commenced its work by reviewing SOs ED01, ED02, and ED11. These SOs were chosen to be the first visited as their interpretation and assessment had proved most problematic over the previous assessment cycle (2009-2013). Initially, the committee attempted to compare the USCGA NA&ME assessment process to other institutions with similar programs of study, but this proved to not be fruitful due to the uniqueness of the program, and that the USCGA NA&ME program already has certain assessment processes established that other institutions do not, like the EOCR process.

The modifications to one SO will be presented in detail here, and the modifications of other SOs will be presented in brevity afterwards. ED01 (An ability to apply knowledge of mathematics, science and engineering) was the first to be revisited. It was realized that as faculty in the same program, there was an implicit understanding of what the word "science" meant, and therefore, this implicit understanding needed to be made explicit: "science" = "physics and chemistry". Likewise with mathematics, there was an implicit understanding that this referred to algebra and calculus (it should be noted that probability and statistics is a separate SO for NA&ME programs).

This then had a ripple effect to the type of BAs that were necessary to properly assess "applying physics knowledge to engineering problems", and "applying chemistry knowledge to engineering problems". Therefore, in order to ensure that the new PI "Apply physics and chemistry knowledge to engineering problems" measured both, one BA was selected to demonstrate physics applications, and another BA was selected to demonstrate chemistry applications.

Similarly, the PI ED01-2 that was modified to "Apply algebra and calculus knowledge to engineering problems" became a direct indicator to have one BA be an algebraic engineering problem and the second to be a calculus engineering problem. Appendix A shows the version of PIs and BAs for all SO prior to this process. Appendix B shows the version after ED01, ED02, and ED11 were modified in 2013-2014, and ED07, ED10, NE03 were modified in 2014-2015. The current stage of reviewing ED03, ED04, and ED09 has been placed on pause after initial review due to the impending ABET changes.

While ED01 had its PIs modified primarily based on a shared understanding among the faculty of what "mathematics" and "science" mean within the major of Naval Architecture and Marine Engineering, others required finessing of the terminology in order to ensure they were measurable. The concept of Bloom's Taxonomy (Bloom et al) was incorporated for this purpose. An example of this was ED11-1. Prior to the review, the initial PI read "Utilize computer software effectively." However, "effectively" did not carry a meaning universally understood. Therefore, it was changed to explain how the software needed to be utilized, "Utilize computer software for creation and analysis of ship designs", where the Bloom's taxonomy verbs of "create" and "analyze" were now incorporated into what utilization of software meant to the program.

After satisfactory modification of the PIs, the BAs were modified to align with the new PIs as well as to be the most accurate indicator of student achievement of a PI. The program has chosen to look at the achievement of SOs holistically with a snapshot at one or two points in the 4-year curriculum. When achievement fails with the holistic approach, an analytic approach to assessment may take place during the EOCR or Program Review, where courses are discussed.

Elements that were considered in the selection of BAs varied from the level of focus that could be derived from a graded element or interview process, to the individuality of the effort for a BA. Group work for a BA was not considered the most accurate assessment of the performance of the individuals in a cohort since many times there is a student who takes the lead in group work, and others may have little to no contribution. Therefore, the grade would not accurately reflect the knowledge of each group member, skewing the BA. Nightly homework assignments are another problematic BA. It has been the experience of the faculty that one year a BA may fail to meet the threshold for a reason not associated with the topic. For example, if the homework was due the same day as there was an exam in another class, students may have not handed in a complete assignment as their attention was diverted. This was obvious on several occasions and noted as such in the EOCR for the respective classes. Additionally, homework assignments, unless required to be individual effort problems, have the same issues as group work with collaboration and can greatly skew the BA results and prove misleading as to individual student performance. For this reason, exam and exam question grades, rubric grades for written reports, and final grades for relevant courses are considered to be more accurate indicators of student performance for BAs.

Some BAs were modified by incorporating grading rubrics to extract the grade just for the segment relevant to the SO, rather than a whole assignment grade.

Since all the changes to the PIs and BAs are taking place over a few short years, the decision was made by the faculty to not change the BA thresholds until BA changes have "settled". The 75% of students in a cohort achieving 70% or better seems to be the most universally appropriate metric during the implementation phase of the changes.

Future Work

The current process has been temporarily halted with the imminent change of ABET going from SOs (a)-(k) to (1)-(7). However, the process has been deemed so successful at interpreting SOs to develop PIs and then to select the appropriate BAs, that it is the plan of the USCGA NA&ME faculty to implement this same process for (1)-(7) over a short one or two year time period in the near future.

Once the new ABET SOs have been implemented, interpreted, and measured for achievement using the PI/BA process for several years, the achievement thresholds will be revisited for each BA. Additionally, the process of continuous improvement never ends. In a few years, the USCGA NA&ME program will be up for ABET accreditation again, and then either this process or something similar will likely be repeated in order to ensure that there is still alignment between the SOs, PIs, and BAs.

Conclusions

A tiered approach to ABET assessment has been presented. SOs are broken into one to three PIs, which are then each measured by student performance on one to three BAs that have been selected to correctly represent the PIs. The PIs provide an interpretation of the SOs for the NA&ME Program. It was decided to have a holistic assessment process.

In order to refine the PIs and BAs, a committee of permanent faculty was formed. Each year, three SOs are visited and reinterpreted through the PIs, attempting to make explicit any implicit understandings and using Bloom's Taxonomy to ensure measurability. Once the PIs associated with the SOs are satisfactory, the BAs are then revisited to ensure they provide a metric for the associated PIs.

Currently, all BA's require 75% of students to individually achieve 70% or higher on a BA. Adjustment to these thresholds will be commenced after all SOs have been revisited. Additionally, the current process has been put on pause until ABET finalizes the current changes to the SOs. When the new ABET SOs are finalized, the current PIs and BAs will first be considered for carryover when possible, and then the process of revisiting SOs to select appropriate PIs and BAs will be completed for the new PIs.

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Appendix A: 2013 Self-Study Student Outcomes, Performance Indicators, and Barometric Assessment mapping to courses. Note: ED01-ED11 correspond to ABET outcomes (a)-(k) and NE01-NE03 are the professional outcomes specific to NA&ME programs.

ED01 – An ability to apply knowledge of mathematics, science and engineering.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED01-1	Apply science knowledge to engineering problems.	1204 Engineering Material Science	Final exam grade
		1211 Dynamics	Final exam grade
ED01-2	Apply math knowledge to engineering problems.	1211 Dynamics	Vibrations HW grade
		1340 Fluid Mechanics	Buckingham Pi HW grade
ED02 – An ability to design and conduct experiments, as well as to analyze and interpret data.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED02-1	Create and conduct an experimental procedure to collect data.	1437 Engineering Experimentation	Final project grade
		1444 Ship Design/System Integration	Tow tank submittal grade
ED02-2	Analyze experimental results to draw supported conclusions.	1437 Engineering Experimentation	Vibrations experiment grade
		1444 Ship Design/System Integration	Tow tank submittal grade
ED03 – 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.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED03-1	Develop design requirements from a set of operational constraints.	1442 Principles of Ship Design	Rubric applied to Mission Analysis submittal
		1356 Ship Structures	Barge project grade
ED03-2	Create a design that meets design requirements subject to engineering standards.	1442 Principles of Ship Design	Executive summary grade
		1444 Ship Design/System Integration	Structure submittal grade
ED04 – An ability to function as a member of multidisciplinary teams.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED04-1	Demonstrate understanding of role of team members.	1442 Principles of Ship Design	Faculty-executed rubric
		1444 Ship Design/System Integration	Faculty-executed rubric
ED04-2	Shares in work of team.	1442 Principles of Ship Design	Teammate contribution rubric
		1444 Ship Design/System Integration	Teammate contribution rubric
ED05 – An ability to identify, formulate and solve engineering problems.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED05-1	Formulate engineering problems using mathematical formulas.	1340 Fluid Mechanics	Design project grade
		1211 Dynamics	Design project grade
ED05-2	Solve engineering problems that involve scientific considerations.	1340 Fluid Mechanics	Final course grade
		1211 Dynamics	Final course grade

ED06 – An understanding of professional and ethical responsibility.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED06-1	Demonstrate a knowledge of professional code of ethics.	1444 Ship Design/System Integration	Rubric applied to class discussion
ED06-2	Recognize the potential for ethical dilemmas in professional practice.	1444 Ship Design/System Integration	Ship design ethical dilemma paper rubric
ED07 – An ability to communicate effectively.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED07-1	Demonstrate effective writing of technical material (clarity, references, graphics).	1442 Principles of Ship Design	Executive summary grade
		1453 Ship Propulsion Design	Individual propeller design submittal grade
ED07-2	Demonstrate effective oral presentation of technical material.	1342 Principles of Naval Architecture	Major-specific argumentative speech rubric
		1444 Ship Design/System Integration	Final presentation grade
ED08 – The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED08-1	Understand the environmental impact of shipping.	6201 Ships and Maritime Systems	Group project presentation grade
		1355 Marine Engineering	Diesel engine emission paper grade
ED08-2	Understand the lifecycle costs of ships.	1342 Principles of Naval Architecture	Cost homework grade
		1442 Principles of Ship Design	Student interview rubric
ED08-3	Understand the global nature of the marine industry.	1442 Principles of Ship Design	Student interview rubric
		6201 Ships and Maritime Systems	Group project presentation grade
ED09 – A recognition of the need for, and an ability to engage in life-long learning.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED09-1	Demonstrate ability to teach/improve oneself beyond classroom.	1342 Principles of Naval Architecture	Major-specific argumentative speech rubric
		6201 Ships and Maritime Systems	Individual stability project grade
ED09-2	Engage in professional development (professional Society, internships, seminars/speakers)	1444 Ship Design/System Integration	Student interview rubric
ED09-3	Demonstrate interest in future professional and academic credentials (take FE, take GRE, identify graduate schools, apply for scholarships/fellowships)	1444 Ship Design/System Integration	Student interview rubric
ED10 – A knowledge of contemporary issues.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED10-1	Demonstrate knowledge of regulatory schemes.	6201 Ships and Maritime Systems	Group project presentation grade
		1356 Ship Structures	ABS HW grade
ED10-2	Awareness of modern maritime engineering challenges.	1442 Principles of Ship Design	Individual research paper grade
		1444 Ship Design/System Integration	Student interview rubric

ED11 – An ability to use techniques, skills, and modern engineering tools necessary for engineering practice.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
ED11-1	Utilize computer software effectively.	1356 Ship Structures	Barge project grade
		1342 Principles of Naval Architecture	Lab average
ED11-2	Demonstrate understanding of use of data collection tools.	1437 Engineering Experimentation	Data acquisition lab grade
		1444 Ship Design/System Integration	Tow tank submittal grade
NE01 – Demonstrate the ability to apply probability and statistical methods to naval architecture and marine engineering problems.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
NE01-1	Apply probability and statistics to NA&ME problems.	1437 Engineering Experimentation	Data uncertainty HW grade
		1444 Ship Design/System Integration	Seakeeping submittal grade
NE02 – Possess a basic knowledge of fluid mechanics, dynamics, structural mechanics, material properties, hydrostatics, and energy/propulsion systems in the context of marine vehicles.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
NE02-1	Demonstrate basic knowledge of fluid mechanics and hydrostatics.	1340 Fluid Mechanics	Final course grade
		1342 Principles of Naval Architecture	Final course grade
NE02-2	Demonstrate basic knowledge of dynamics.	1211 Dynamics	Final course grade
NE02-3	Demonstrate basic knowledge of ship structure and materials.	1356 Ship Structures	Final exam grade
		1204 Engineering Material Science	Final exam grade
NE02-4	Demonstrate basic knowledge of energy/propulsion systems	1453 Ship Propulsion Design	Final course grade
		1355 Marine Engineering	Final exam grade
NE03 – Exhibit familiarity with instrumentation appropriate to Naval Architecture and/or Marine Engineering including experiment design, data collection, analysis, and formal report writing.			
Performance Indicators		Barometric Assessment Courses	Barometric Assessment
NE03-1	Demonstrate familiarity with mechanical instrumentation.	1437 Engineering Experimentation	Strain gage HW grade
		1444 Ship Design/System Integration	Tow tank submittal grade
NE03-2	Demonstrate familiarity with fluid instrumentation.	1437 Engineering Experimentation	Pressure sensor lab grade
		1340 Fluid Mechanics	Manometer HW grade

Appendix B: Current (2016) Student Outcomes, Performance Indicators, and Barometric Assessment mapping to courses. Note: ED01-ED11 correspond to ABET outcomes (a)-(k) and NE01-NE03 are the professional outcomes specific to NA&ME programs.

ED01 – An ability to apply knowledge of mathematics, science and engineering.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED01-1	Apply physics and chemistry knowledge to engineering problems.	1204 Engineering Material Science	Final exam grade
		1211 Dynamics	Final exam grade
ED01-2	Apply algebra and calculus knowledge to engineering problems.	1211 Dynamics	Vibrations Individual effort HW, Quiz, or Exam grade
		3301 Advanced Engineering Mathematics	Linear Algebra Exam Grade
ED02 – An ability to design and conduct experiments, as well as to analyze and interpret data.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED02-1	Design and conduct an experimental procedure to collect data.	1437 Engineering Experimentation	Experiment design project grade (grading rubric needed)
		1444 Ship Design/System Integration	Tow tank submittal grade (rubric – setup/procedure)
ED02-2	Analyze experimental results to draw supported conclusions.	1355 Marine Engineering	Engine test bed grade (rubric for results/conclusions?)
		1444 Ship Design/System Integration	Tow tank submittal grade (rubric – analysis)
ED03 – 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.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED03-1	Develop design requirements from a set of operational constraints.	1442 Principles of Ship Design	Rubric applied to Mission Analysis submittal
		1356 Ship Structures	Barge project grade
ED03-2	Create a design that meets design requirements subject to engineering standards.	1442 Principles of Ship Design	Executive summary grade
		1444 Ship Design/System Integration	Structure submittal grade
ED04 – An ability to function as a member of multidisciplinary teams.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED04-1	Demonstrate understanding of role of team members.	1442 Principles of Ship Design	Faculty-executed rubric
		1444 Ship Design/System Integration	Faculty-executed rubric
ED04-2	Shares in work of team.	1442 Principles of Ship Design	Teammate contribution rubric
		1444 Ship Design/System Integration	Teammate contribution rubric

ED05 – An ability to identify, formulate and solve engineering problems.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED05-1	Formulate engineering problems using mathematical formulas.	1340 Fluid Mechanics	Design project grade
		1211 Dynamics	Design project grade
ED05-2	Solve engineering problems that involve scientific considerations.	1340 Fluid Mechanics	Final course grade
		1211 Dynamics	Final course grade
ED06 – An understanding of professional and ethical responsibility.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED06-1	Demonstrate a knowledge of professional code of ethics.	1444 Ship Design/System Integration	Rubric applied to class discussion
ED06-2	Recognize the potential for ethical dilemmas in professional practice.	1444 Ship Design/System Integration	Ship design ethical dilemma paper rubric
ED07 – An ability to communicate effectively.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED07-1	Demonstrate effective writing of technical material (clarity, references, graphics, etc.).	1355 Marine Engineering	Major-specific position paper rubric
		1453 Ship Propulsion Design	Individual propeller design submittal grade
ED07-2	Demonstrate effective oral presentation of technical material.	1355 Marine Engineering	Major-specific position speech rubric
		1444 Ship Design/System Integration	Final presentation grade
ED08 – The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED08-1	Understand the environmental impact of shipping.	6201 Ships and Maritime Systems	Group project presentation grade
		1355 Marine Engineering	Diesel engine emission paper grade
ED08-2	Understand the lifecycle costs of ships.	1342 Principles of Naval Architecture	Cost homework grade
		1442 Principles of Ship Design	Student interview rubric
ED08-3	Understand the global nature of the marine industry.	1442 Principles of Ship Design	Student interview rubric
		6201 Ships and Maritime Systems	Group project presentation grade
ED09 – A recognition of the need for, and an ability to engage in life-long learning.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED09-1	Demonstrate ability to teach/improve oneself beyond classroom.	1342 Principles of Naval Architecture	Major-specific argumentative speech rubric
		6201 Ships and Maritime Systems	Individual stability project grade
ED09-2	Engage in professional development (professional Society, internships, seminars/speakers)	1444 Ship Design/System Integration	Student interview rubric
ED09-3	Demonstrate interest in future professional and academic credentials (take FE, take GRE, identify graduate schools, apply for scholarships/fellowships)	1444 Ship Design/System Integration	Student interview rubric

ED10 – A knowledge of contemporary issues.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED10-1	Demonstrate a knowledge of contemporary issues relevant to Naval Architecture & Marine Engineering (regulatory schemes, politics, new technologies, etc)	1442 Principles of Ship Design	Student interview rubric
		1444 Ship Design/System Integration	Final presentation grade
ED11 – An ability to use techniques, skills, and modern engineering tools necessary for engineering practice.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
ED11-1	Utilize computer software for creation and analysis of ship designs. .	1453 SPD	Propulsor Selection submittal grade
		1442 Principles of Ship Design	Hull Geometry Submittal (Focused Rubric?)
ED11-2	Assess ship performance (e.g. stability and resistance) using accepted industry practices.	1342 Principles of Naval Architecture	Inclining experiment laboratory grade
		1444 Ship Design/System Integration	Tow tank submittal grade (rubric – analysis of results)
NE01 – Demonstrate the ability to apply probability and statistical methods to naval architecture and marine engineering problems.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
NE01-1	Apply probability and statistics to NA&ME problems.	1437 Engineering Experimentation	Data uncertainty HW grade
		1444 Ship Design/System Integration	Seakeeping submittal grade
NE02 – Possess a basic knowledge of fluid mechanics, dynamics, structural mechanics, material properties, hydrostatics, and energy/propulsion systems in the context of marine vehicles.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
NE02-1	Demonstrate basic knowledge of fluid mechanics and hydrostatics.	1340 Fluid Mechanics	Final course grade
		1342 Principles of Naval Architecture	Final course grade
NE02-2	Demonstrate basic knowledge of dynamics.	1211 Dynamics	Final course grade
NE02-3	Demonstrate basic knowledge of ship structure and materials.	1356 Ship Structures	Final exam grade
		1204 Engineering Material Science	Final exam grade
NE02-4	Demonstrate basic knowledge of energy/propulsion systems	1453 Ship Propulsion Design	Final course grade
		1355 Marine Engineering	Final exam grade
NE03 – Exhibit familiarity with instrumentation appropriate to Naval Architecture and/or Marine Engineering including experiment design, data collection, analysis, and formal report writing.			
	Performance Indicators	Barometric Assessment Courses	Barometric Assessment
NE03-1	Demonstrate familiarity with instrumentation appropriate to Naval Architecture and/or Marine Engineering including experiment design, data collection, analysis, and formal report writing.	1437 Engineering Experimentation	Final Design Project
		1444 Ship Design/System Integration	Tow tank submittal grade