Adjusting to the New ABET Criteria 3 and 5: It's Really Not Very Hard

Dr. Allen C Estes, California Polytechnic State University, San Luis Obispo

Allen C. Estes is a Professor and Head for the Architectural Engineering Department at California Polytechnic State University in San Luis Obispo. Until January 2007, Dr. Estes was the Director of the Civil Engineering Program at the United States Military Academy (USMA). He is a registered Professional Engineer in Virginia. Al Estes received a B.S. degree from USMA in1978, M.S. degrees in StructuralEngineering and in Construction Management from Stanford University in 1987 and a Ph.D. degree in Civil Engineering from the University of Colorado at Boulder in 1997.

Dr. Peter Laursen

Dr. Peter Laursen, P.E., is an Associate Professor of Architectural Engineering at the California Polytechnic State University, San Luis Obispo (Cal Poly) where he teaches courses on the analysis and design of structural systems including laboratory courses.

Dr. Pamalee A. Brady, California Polytechnic State University, San Luis Obispo

Pamalee Brady is a Professor at California Polytechnic State University, San Luis Obispo. She teaches courses in structural systems, concrete, steel and wood design as well as structural engineering courses for architecture and construction management students. Prior to joining the faculty at Cal Poly she worked in applied research at the U.S. Army Construction Engineering Research Laboratory in Champaign, Illinois. She is a member of the Education Committee of the ASCE Forensic Engineering Division and an Associate Editor of the ASCE Journal of Performance of Constructed Facilities. Her research is in the areas of engineering education, including engineering case studies in undergraduate education.

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Abstract

ABET has revised the criteria 3 (Student Outcomes) and 5 (Curriculum) of the general criteria. These changes have made it through the rigorous approval process and will be effective for the 2019-20 academic year. This paper analyzes the differences between the existing criteria and the proposed changes. Through a specific detailed example, the paper illustrates how an existing assessment system can seamlessly be adjusted for the new criteria. Most of the embedded indicators and direct measures of attainment can still be used. The results simply need to be organized differently.

Introduction

Proposed changes to certain sections of the Criteria for Accrediting Engineering Programs have been approved by the ABET Engineering Area Delegation as of October 20, 2017 for implementation in the 2019–20 accreditation review cycle. The changed sections are the Introduction and Definitions that apply to all parts of the engineering accreditation criteria and Criterion 3, (Student Outcomes) and Criterion 5 (Curriculum) of the General Criteria for Accrediting Baccalaureate Level Programs.

Changes to the general criteria occur infrequently. In this case, the eleven familiar criterion 3 a-k student outcomes are being replaced by seven new student outcomes. Because the attainment of student outcomes must be assessed and reported in self-studies, this appears to be a major change that will require programs to perform an extensive overhaul of their existing assessment systems. In reality, the actual changes in accreditation requirements are very small and can be accommodated with relatively little effort. In most cases, the new requirements are easier to meet than the existing requirements and present increased flexibility for many programs.

Criterion 3 Changes

The current Criterion 3 (a)-(k) student outcomes[1] which have been unchanged since they were adopted as part of EC2000 are:

Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.
(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) 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
(d) an ability to function on multidisciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility

(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

The current Criterion 3 (a)-(k) student outcomes have been revised into a new Criterion 3 (1)-(7) set of student outcomes[1] shown below. The history of these changes and rationale behind them has been documented by ABET.[2,3]

The program must have documented student outcomes that support the program educational objectives. Attainment of these outcomes prepares graduates to enter the professional practice of engineering. Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program.
(1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
(2) an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
(3) an ability to communicate effectively with a range of audiences
(4) an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
(5) an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
(6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
(7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Criterion 5 Changes

The current Criterion 5 Curriculum requirements[1] are also unchanged since they were adopted as part of EC2000 are:

The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The faculty must ensure that the program curriculum devotes adequate attention and time to each component, consistent with the outcomes and objectives of the program and institution. The professional component must include:
(a) one year of a combination of college level mathematics and basic sciences (some with experimental experience) appropriate to the discipline. Basic sciences are defined as biological, chemical, and physical sciences.

(b) one and one-half years of engineering topics, consisting of engineering sciences and engineering design appropriate to the student's field of study. The engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward creative application. These studies provide a bridge between mathematics and basic sciences on the one hand and engineering practice on the other. Engineering design is the process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.
(c) a general education component that complements the technical content of the curriculum and is consistent with the program and institution objectives.
Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints.
One year is the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation.

Proposed changes to Criterion 5 Curriculum of the Criteria for Accrediting Engineering Programs[1] are:

The curriculum requirements specify subject areas appropriate to engineering but do not prescribe specific courses. The program curriculum must provide adequate content for each area, consistent with the student outcomes and program educational objectives, to ensure that students are prepared to enter the practice of engineering. The curriculum must include:
(a) a minimum of 30 semester credit hours (or equivalent) of a combination of college-level mathematics and basic sciences with experimental experience appropriate to the program.
(b) a minimum of 45 semester credit hours (or equivalent) of engineering topics appropriate to the program, consisting of engineering and computer sciences and engineering design, and utilizing modern engineering tools.
(c) a broad education component that complements the technical content of the curriculum and is consistent with the program educational objectives.
(d) a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.

Relevant Changes

- **Multi-disciplinary teams.** Both the existing criteria and the new criteria require the students to work in teams. While the new criterion 3(5) adds verbiage about leadership, collaboration, goals, tasks and objectives, these are integral parts of working in teams and don't really create anything new. What is missing from the new criteria is the requirement for multi-disciplinary teams, which is surprising considering the increased industry emphasis on this skill. Working across disciplines is difficult.[4,5,6] and this constraint has been removed from the accreditation process. This is not a major change for the civil engineering programs. The civil engineering program commentary[7] states that teams with members in more than one of the recognized sub-disciplines of civil engineering (geotechnical, structures, hydrology, environmental, construction or transportation) are multi-disciplinary, which greatly reduced the burden of this requirement.

- **Lifelong learning…no longer an attitude.** Existing Criterion 3(i) required a recognition of the need for life-long learning rather that the requirement to actually do any life-long learning. It was the measure of an awareness or an attitude, which can be directly measured through a survey. It can be measured by the intent to join professional societies, attain a graduate degree, or attend continuing education workshops. The new criterion 3 removes the word "life-long" and makes it less lofty and more specific to what students should be able to do by graduation. Students must acquire and apply new knowledge as needed, using appropriate learning strategies. To demonstrate attainment of the new outcome, a program should require students to learn some aspect of the curriculum on their own. Examples might include a new software program, a technical concept in an engineering class, or the use of a piece of equipment for an experimental purpose. The assignments could be prefaced with guidance on appropriate learning strategies.

- **Range of audiences … makes objectives more difficult.** Current criterion 3(d) requires that students communicate effectively and the new criterion 3(3) adds the provision to communicate effectively with a range of audiences. The addition should have no effect on the program assessment of student outcomes as most curricula have students communicate with faculty, peers within their discipline, peers outside their discipline and members of industry, which constitute an array of audiences. It does make developing program objectives more difficult. Program objectives which describe what students can do three to five years after graduation must be noticeably different from student outcomes and can result in a shortcoming when they are not. It is difficult in the area of effective communication to make the student outcome different from a program objective. One way to highlight this difference is to make the program objective reflect higher level communication with a wider range of audiences over a greater variety of topics than what a student does at the time of graduation. By adding range of audiences to the student outcome, the accompanying program objective is more difficult to craft.

- **Design of experiments.** Current criterion 3(b) requires that students design and conduct experiments. This has been a challenge for civil engineering programs because civil engineers do not usually design experiments. This requirement has affected the Civil Engineering Body of Knowledge (BOK)[8] ,the interface with the Civil Engineering Program Criteria[9] and the specified level of attainment at the undergraduate level. The new criterion 3(6) more reasonably requires that students develop and conduct appropriate experimentation and use engineering judgement. This is more realistic and indicative of what civil engineers actually do. Programs will no longer have to artificially place a design of experiment into the curriculum[10]. Hopefully, the BOK can be more realistic and the issue will not have to be finessed in the commentary.[7]

- **Beware combined outcomes.** In the process of revising criterion 3, some outcomes were combined with the intent of simplifying the assessment process and eliminating redundancies. This works well where current student outcomes 3(a) and 3(e) were combined to create the new student outcome 3(1) which requires an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. The outcomes are compatible and examples of attainment are plentiful in any engineering program. It works less well as current student outcomes 3(f), 3(h), and 3(i) were combined into new student outcome 3(4) which requires an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. These are not compatible and do not naturally belong in the same student outcome. The danger for a program is that they might assess one aspect of the outcome and miss the other which could result in a shortcoming that might otherwise be avoided by keeping these outcomes separate. Ethics and professional responsibility are important concepts and are muddied by including global, economic, environmental, and societal contexts into the requirements. The need for global, economic, environmental, and societal awareness also extends beyond just the areas of ethics and professional responsibility. It will be difficult for programs to find elements in the curricula that meet all of this. One solution is to keep the separate indicators that already exist in current assessment processes. The pitfall is that they could be lost over time. Programs should also note that the criterion states, "global, economic, environmental, **and** societal" which indicates that all must be assessed, and increases the likelihood of one being missed.

- **What gets included in engineering design.** Current criterion 3(c) requires that engineering design "meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability". The word "such as" indicates that only a relevant sampling from that list needs to be included. In the new criterion student outcome 3(2), engineering design solutions must meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. It is far less clear whether some or all of these need to be included. In addition, in the definitions section of the new criterion, the definition of engineering design includes possible constraints to be considered as "accessibility, aesthetics, codes, constructability, cost, ergonomics, extensibility, functionality, interoperability, legal considerations, maintainability, manufacturability, marketability, policy, regulations, schedule, standards, sustainability, or usability."[1] The exact requirements will only become apparent over time.

- **Current tools and technology.** The current student outcome 3(k) which requires students to use the techniques, skills, and modern engineering tools necessary for engineering practice, has been eliminated as a student outcome and has been moved to Criterion 5 where utilizing modern engineering tools is included in the description of Engineering Science. A program will no longer need to demonstrate that students are able to use these modern tools; they must merely demonstrate that they are included in the curriculum.

- **Definition of a year.** The most substantive and beneficial change occurs in the new Criterion 5 where a year is defined as 30 semester hours. This is a vast improvement over the previous dual definition which defined a year as the lesser of 32 semester hours (or equivalent) or one-fourth of the total credits required for graduation. This existing criterion has proven difficult for many programs to meet and many found themselves adding math or science courses that they did not want to meet this criterion.[11] Furthermore, the amount of math and science that an engineer needs should rightfully not depend on the number of total units in the program. By lowering the definition to a common 30 semester hours, the standard is fairer, more attainable, and provides more flexibility for an engineering program.

- **Bottom line.** The conclusion is that very little of substance has changed in the revision of Criteria 3 and 5. Almost nothing new has been either added or eliminated even though the order has changed considerably. It should be easy for a program to adjust to the new criteria and the rest of the paper illustrates that using the specific example of a program that has done it.

Incorporating the New Changes

Most accredited engineering programs have been through three iterations of the EC2000 criteria and have well-developed assessment methodologies that demonstrate attainment of the current ABET 3 a-k student outcomes. Because the substantive changes are minor, those methodologies can still be used. Only the order and arrangement of the assessment instrument needs to change. This section illustrates the point using the example of an actual engineering program that has switched to the new criteria. This program follows a methodology that has been commonly referenced in the literature[12,13,14] and has been presented multiple times at the annual ASCE Civil Engineering Department Heads Conferences[15,16,17]. These ideas are one of many possible approaches to program assessment, but the concepts are hopefully applicable to most programs. For meeting the ABET criteria 3 and 4, the process is as follows:

Develop student outcomes. ABET has provided seven student outcomes, but the criterion invites programs to develop its own in addition to those. Some programs choose to alter the seven outcomes to reflect the strengths and uniqueness of their specific program. This was encouraged in the early years of EC2000, but it became clear to most programs that this provided little benefit and potentially caused problems.[11] Today most programs use the ABET criterion 3 student outcomes verbatim. This example takes that approach.

Identify where in the curriculum these outcomes are met. The student outcomes are generally attained through the curriculum, which for most programs means four years of targeted coursework. It is therefore important to assess the degree to which any course in the curriculum supports the attainment of each student outcome. Some programs will create a table and use an ‘x’ to indicate whether a course does or does not contribute to an outcome. Greater fidelity is both possible and advisable. The partial course/outcome matrix shown in Table 1 was developed by evaluating the contribution of each course to each student outcome. The ABET Committee created the matrix and it was reviewed and independently verified by the Curriculum Committee. The relative contributions of each course were assessed using a 1 to 5 Likert Scale applying the following rubric:

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

The complete matrix contains all 56 courses in the curriculum. This institution is on the quarter system which accounts for the high number of courses. It was a straight-forward exercise to repeat the process using the seven student outcomes in the new criteria as shown in Table 2.

Collect relevant data for assessing each outcome. There are a variety of data available for determining the degree to which a student outcome is attained. The most credible data are direct measures of student performance such as results from the Fundamentals of Engineering (FE) exam, opinions of outside experts, and targeted student performance on specific assignments. The FE exam in a nationally-normed exam with unbiased results. Programs are provided with feedback on student performance in a variety of areas ranging from calculus and chemistry to ethics and engineering economics. The discipline-specific versions of the exam provide even richer data. If a program can establish that a sufficient number of students in the program have taken the FE exam, the results are highly credible for measuring those student outcomes where the subject being reported correlates with a specific student outcome. Expert opinion provides good data for student communication skills, technical expertise, and even things like global, economic, social understanding of engineering. Industry partners are often providers of this opinion. The measures need to be taken in a structured manner.

Some programs create special instruments to provide direct measure data on student performance. If the curriculum is covering all of the student outcomes, there should be enough indicators embedded in the curriculum that specially created additional activities are not necessary. The most available and versatile embedded indicators[18] are the results of course activities such as quizzes, texts, projects, laboratory experiments, presentations and papers. The course event needs to correlate directly to the student outcome being assessed. The course/outcome matrix in Tables 1 and 2 have several benefits. It allows a program director to see which courses are contributing most toward each outcome, thus providing guidance for where the student performance assessments should occur. The matrix also shows if there are no courses contributing to an outcome — a significant

Rubric 5: Very large contribution; many examples of student work that directly contribute; outcome is a course objective 4: Substantial contribution; some examples of student work that directly correlate to outcome; not an explicit course objective 3: Some contribution; elements of outcome covered in course; no student work that directly contributes 2: Marginal contribution; no student work; outcome only covered tangentially by text or instructor 1: No identifiable contribution of course to program outcome	**(a) An ability to apply knowledge of mathematics, science and engineering to building structures and materials.**	**(b) An ability to design and/or conduct experiments, as well as to analyze and interpret data**	**(c) An ability to design a building system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.**	**(d) An ability to function in interdisciplinary teams for the design and construction of buildings**	**(e) An ability to identify, formulate and solve structural engineering problems**	**(f) An understanding of professional and ethical responsibility**	**(g) An ability to communicate effectively**	**(h) The broad education necessary to understand the impact of engineering solutions in a global and societal context**	**(i) A recognition of the need for and an ability to engage in life-long learning**	**(j) A knowledge of how the built environment is related to contemporary issues**	**(k) An ability to use the techniques, skills and tools necessary for structural engineering practice**	**(l) Application of construction and constructability issues in buildings.**
ARCE 106/CM113	1	1	3	3	1	1	2	1	2	1	2	4
ARCH 131	1	1	3	4	1	1	3	1	1	3	3	1
ARCH 132	1	1	3	4	1	1	3	1	1	3	3	1
ARCH 133	1	1	3	4	1	1	3	1	1	3	3	1
CM 115	2	1	3	3	1	4	5	1	1	2	5	5
ARCH 217/218/219	1	1	1	1	1	1	2	4	3	4	1	1
ARCE 260	1	1	1	1	1	1	2	4	3	4	1	1
EDES 101	1	1	1	2	1	3	1	2	3	3	2	3
CM 332/IME 314	2	3	4	2	1	3	2	3	1	3	4	4
CSC231/234	4	4	2	1	3	1	3	1	1	1	3	1
EE 201	3	2	1	1	1	1	1	1	1	1	1	1

Table 1: Course-Outcome Matrix for current ABET Criteria 3 Student Outcomes

Rubric 5: Very large contribution; many examples of student work that directly contribute; outcome is a course objective 4: Substantial contribution; some examples of student work that directly correlate to outcome; not an explicit course objective 3: Some contribution; elements of outcome covered in course; no student work that directly contributes 2: Marginal contribution; no student work; outcome only covered tangentially by text or instructor 1: No identifiable contribution of course to program outcome	**1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.**	**2) An ability to apply the engineering design process to produce solutions that meet specified needs with consideration for public health and safety, and global, cultural, social, environmental, economic, and other factors as appropriate to the discipline.**	**3) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.**	**4) An ability to communicate effectively with a range of audiences.**	**5) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.**	**6) An ability to recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge.**	**7) An ability to function effectively as a member or leader of a team that establishes goals, plans tasks, meets deadlines, and creates a collaborative and inclusive environment.**
ARCE 106	1	3	1	5	4	3	5
ARCH 131	1	2	1	3	1	3	4
ARCH 132	1	2	1	3	1	3	4
ARCH 133	1	2	1	3	1	3	4
ARCE 260	1	3	1	5	2	3	1
CM 115	2	3	1	3	3	3	3
ARCH 217/218/219	1	2	1	3	2	2	1
BRAE 237/239	2	2	3	2	2	2	3
CM 232/IME 314	3	3	1	2	3	3	1
CSC231/234	3	2	1	2	1	2	1
STAT 312/321	3	2	2	2	1	3	1
EE 201	5	3	3	2	2	3	1

Table 2: Course-Outcome Matrix for new ABET Criteria 3 Student Outcomes

problem that should be addressed by either changing the outcome or making a curriculum change to better incorporate the outcome into the program curriculum. A course/outcome matrix does not constitute a demonstration of outcome achievement; it merely points toward the specific courses in which high-quality measurements of outcome achievement are most likely to be obtained. Those courses with a rating of 5 should provide the greatest source of embedded indicators. Once these embedded indicators are identified, the faculty member(s) teaching the courses in which they appear can be assigned to report the results for any given quarter or semester.

Figure 1 shows a sample assignment sheet that can be used for this collection.

- **Outcome (a): An ability to apply knowledge of mathematics, science and engineering to building structures and materials.**
    - ARCE 302 final exams. Anahid (Fall Qtr)
    - ARCE 444 final exams. Cole, Craig (Fall Qtr)
- **Outcome (b): An ability to design and/or conduct experiments, as well as to analyze and interpret data.**
    - ARCE 421 Final exam Larry (Fall Qtr).
    - ARCE 223 lab: stress-strain lab report James (Fall Qtr)
    - ARCE 223 lab: designed experiment. James (Fall Qtr)
    - ARCE 353 truss experiment Peter (Fall Qtr)
- **Outcome (c): An ability to design a building system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.**
    - ARCE 452: final project grade (Winter Qtr)
    - ARCE 483: pushover analysis of a frame assignment Cole (Fall Qtr);

Figure 1: Annual Embedded Indicators for a Program Assessment

1. **Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics:**
    a. ARCE 483 final exam Peter, Cole (Fall) Peter (Spring)
    b. ARCE 302 final exam Radu (Fall), Al (Winter)
    c. ARCE 372 calc package Pamalee, Michael (Fall), Jill, Michael (Spring)
    d. ARCE 354 modal analysis Anahid (Winter, Spring)
2. **Ability to apply the engineering design process to produce solutions that meet specified needs with consideration for public health and safety, and global, cultural, social, environmental, economic, and other factors as appropriate to the discipline:**
    a. ARCE 415 final project submittal Dennis (Fall), Ed (Winter, Spring)
    b. ARCE 372 final project Pamalee, Michael (Fall), Jill, Michael (Spring)
    c. ARCE 451 final project John, Craig, Jill (Fall), Brent (Spring)
3. **Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions:**
    a. ARCE 444 beam test Pamalee, Anahid (Fall), Craig (Winter)
    b. ARCE 421 soils test Dahlia (Fall, Winter, Spring)
    c. ARCE 224 – selected lab Peter (Fall), Craig (Spring)

Figure 2: Assigned Embedded Indicators for the New Criteria 3 Outcomes

Because the substance of the Criteria 3 changes is minimal, the good news for programs with established systems is that few, if any, new indicators are needed. They simply need to be reallocated to the new outcomes as shown in Figure 2.

Senior Survey– Focused Questions
Architectural Engineering Program

As seniors who are getting close to graduation, we are soliciting your input with respect to the Architectural Engineering program outcomes. A program outcome defines what we expect that you are able to do upon graduation. Please use the following 1 to 5 scale when asked to rate your response:

a = Excellent **b = Very Good** **c = OK** **d = Not Good** **e = Terrible**

With respect to the program outcomes listed below, rate your own ability to:

1.	**a**	**b**	**c**	**d**	**e**	apply knowledge of mathematics, science and engineering to building structures.
2.	**a**	**b**	**c**	**d**	**e**	design and conduct experiments, as well as to analyze and interpret data
3.	**a**	**b**	**c**	**d**	**e**	design a building system, component, or process to meet desired needs within realistic constraints such as regulatory, economic, environmental, social, political, ethical, health and safety, constructability, and sustainability
4.	**a**	**b**	**c**	**d**	**e**	function in interdisciplinary teams for the design and construction of buildings.
5.	**a**	**b**	**c**	**d**	**e**	identify, formulate and solve structural engineering problems
6.	**a**	**b**	**c**	**d**	**e**	understand professional and ethical responsibility
7.	**a**	**b**	**c**	**d**	**e**	communicate effectively using graphics
8.	**a**	**b**	**c**	**d**	**e**	write effectively
9.	**a**	**b**	**c**	**d**	**e**	speak effectively
10.	**a**	**b**	**c**	**d**	**e**	understand the impact of engineering solutions in a global and societal context.
11.	**a**	**b**	**c**	**d**	**e**	recognize the need for and to engage in life-long learning
12.	**a**	**b**	**c**	**d**	**e**	explain how the built environment is related to contemporary issues
13.	**a**	**b**	**c**	**d**	**e**	use the techniques, skills and tools necessary for structural engineering practice
14.	**a**	**b**	**c**	**d**	**e**	recognize the construction and constructability issues in buildings

Table 3: Existing student survey based on the ABET 3(a)-(k) student outcomes

Architectural Engineering 2018 Faculty Survey
The goal of this survey is to give the ARCE faculty an opportunity to assess student attainment of ARCE program outcomes

Attainment: Identify your perceived level of attainment of each Educational Objective in the Attainment column: NA =not applicable, 1 =not attained, 2 =minimally attained, 3 =somewhat attained, 4 =attained, and 5 =strongly attained.		**Importance**: Rate how important you perceive each Educational Objective is to your professional education: NA =not applicable, 1 =low value, 2 =little value, 3 =neutral, 4 =some value, and 5 = high value.
Educational Outcomes: what we expect our graduates to be able to do at the time of graduation	**Attainment**	**Importance**
1. identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
2. apply the engineering design process to produce solutions that meet specified needs with consideration for public health and safety, and global, cultural, social, environmental, economic, and other factors as appropriate to the discipline.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
3. develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
4. communicate effectively with a range of audiences.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
4a. communicate effectively orally	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
4b. communicate effectively in writing	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
4c. communicate effectively graphically.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
5. recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
6. recognize the ongoing need to acquire new knowledge, to choose appropriate learning strategies, and to apply this knowledge	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐
7. function effectively as a member or leader of a team that establishes goals, plans tasks, meets deadlines, and creates a collaborative and inclusive environment.	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐	NA 1 2 3 4 5 ☐ ☐ ☐ ☐ ☐ ☐

Table 4: A faculty survey that has been modified to reflect the new ABET Student Outcomes

Other measures of student outcome attainment are indirect measures such as surveys of faculty, industry members who hire the graduates, or even the students themselves. Often the surveys are simply Likert scale questions asking the respondents to render an opinion on the attainment and perhaps even the importance of an individual student outcome. While not as valid as actual performance data, survey data are easier to obtain and provide results for some of the squishier outcomes that are harder to measure[20]. With the new criteria, the survey instrument simply needs to be revised to reflect the new student outcomes as shown in Tables 3 and 4.

The least reliable data come from using course grades as measures. ABET has contended for a long time that course grades are not an accurate assessment tool[19] because too many variables are involved. Course grades can still be effective, especially for general education courses outside of an engineering college where tracking student progress through embedded indicators is not practical. Having taken and passed courses that relate to a specific outcome contributes to the case of outcome attainment, even if course grades are not sufficient by themselves. If course grades from courses outside the department are currently being used to support specific outcomes, those same course grades most likely apply to the new outcomes and can still be used.

As with the ABET 3(a)-(k) outcomes, the new student outcomes offer areas that are difficult to measure such as life-long learning, ethics, and considering the impact of engineering solutions from global, economic, environmental, and societal contexts. The solutions that are valid under the existing criteria such as creating rubrics, assigning a student outcome to a particular course, and using the capstone culminating experience to capture data[20] can still be used. Typically capstone courses have complex rubrics where the grades are divided into manageable parts as shown in Table 5. It is very practical to require a project group to explicitly address the global, societal, environmental, and economic implications of their project and include those elements as separate elements of the rubric.[21,22]

Establish performance measures for each outcome. Once the relevant data are identified, the faculty develop the desired performance measures that would indicate successful attainment of the outcome. After considerable discussion, the desired result for most of the embedded indicators in this program was 75%. While 70% is passing, accepting that score as an average would indicate that too many students did not meet the standard. This program has a well-earned reputation for very tough, uninflated grading and a standard of 80% would be too high as the minimum standard. The performance measure of 75% was a balance between those two philosophical concerns. For the FE exam, the performance standard is to be at or above the national average as reported by the National Council of Examiners for Engineering and Surveying (NCEES) to the institution.

For those survey questions where the response was a 1–5 Likert scale, the desired minimum standard was 4.0 for most questions. The exception was on the curriculum measures where the standard was tied to the faculty assessment of an outcome's relative importance to the architectural engineering program. Student outcomes rated as less important have a lower standard of attainment and vice-versa.

Once the performance measures are established and the relevant data are collected, the results are assembled, analyzed and rated with respect to each outcome. The data are separated into direct measures, indirect measures, and curriculum measures. The curriculum measures account for the level that the outcome was covered in the curriculum and was based on the number of courses that attained level 4 or 5 contributions in the course-outcome matrix in Tables 1 and 2. The number of courses that should fall in the 4 or 5 level is related to the importance of the outcome to the overall curriculum as assessed by the faculty and advisory board members. The philosophy is that the more important outcomes should receive the greater coverage in the curriculum. With the new Criterion 3 outcomes, there is no reason that any of these standards need to change.

10 % Design Requirements:	Pos Points	Grade Percentage										Min %	Max %	Ave
		Grp 1	Grp 2	Grp 3	Grp 4	Grp 5	Grp 6	Grp 7	Grp 8	Grp 9	Grp 10			
Admin Requirements	15	90%	97%	83%	100%	100%	87%	97%	83%	90%	90%	83%	100%	92%
Title Sheet	5	100%	100%	100%	100%	100%	70%	100%	100%	100%	100%	70%	100%	97%
Executive Summary	5	100%	100%	100%	100%	100%	100%	50%	100%	100%	100%	50%	100%	95%
Drawing List	5	100%	100%	0%	100%	100%	60%	50%	100%	50%	100%	0%	100%	76%
Notes Page	5	100%	70%	0%	10%	10%	70%	40%	0%	10%	80%	0%	100%	39%
Project Scope	5	100%	100%	100%	100%	100%	80%	60%	40%	70%	100%	40%	100%	85%
Facts and Assumptions	5	100%	100%	90%	90%	100%	70%	60%	80%	60%	100%	60%	100%	85%
Needs Analysis	5	100%	100%	90%	100%	100%	60%	50%	80%	60%	100%	50%	100%	84%
Discussion and Results	15	87%	87%	87%	80%	100%	100%	100%	60%	80%	100%	60%	100%	88%
Existing Site Plan	5	80%	90%	80%	80%	80%	70%	70%	70%	70%	80%	70%	90%	77%
Site Use Plan	10	65%	90%	0%	85%	75%	45%	45%	40%	70%	85%	0%	90%	60%
Site Prep and Demo Plan	5	0%	90%	60%	100%	80%	100%	60%	50%	80%	100%	0%	100%	72%
Exterior Architectural Elevations	20	85%	90%	85%	88%	95%	53%	80%	35%	80%	88%	35%	95%	78%
Architectural Roof Plan	5	30%	90%	90%	90%	90%	40%	60%	60%	60%	90%	30%	90%	70%
Architectural Floor Plans	35	77%	94%	89%	86%	91%	77%	83%	66%	80%	91%	66%	94%	83%
Life Safety Floor Plans	20	20%	95%	0%	95%	100%	50%	85%	35%	75%	95%	0%	100%	65%
Typical Details	15	40%	100%	93%	73%	100%	87%	73%	43%	80%	93%	40%	100%	78%
Arch. Floor Plan & Access/Egress Calcs	15	0%	93%	87%	97%	90%	80%	57%	0%	53%	87%	0%	97%	64%
Load Analysis	15	67%	97%	90%	77%	100%	53%	53%	43%	80%	93%	43%	100%	75%
Soil and Foundation Plan Calculations	10	100%	100%	100%	100%	100%	100%	100%	100%	80%	100%	80%	100%	98%
Drainage Plan Calculations	15	83%	97%	67%	100%	80%	93%	33%	67%	80%	100%	33%	100%	80%
Environmental Considerations	5	100%	100%	90%	100%	100%	90%	100%	50%	60%	60%	50%	100%	85%
Cost Estimates	5	60%	70%	60%	100%	80%	60%	80%	80%	60%	80%	60%	100%	73%
Documentation (coordination with key players)	5	90%	100%	100%	100%	100%	100%	90%	50%	60%	100%	50%	100%	89%
10% Design Total	**250**													

Table 5: Typical grading rubric for a Capstone Design course

Evaluate student performance against these measures and provide a rating. Each student outcome is evaluated with respect to each relevant data point. Table 6 shows the academic year 2016-2017 results for ABET student outcome 3a. A similar table was established for each outcome and an overall score was assigned to reflect the attainment of the outcome according to the following rubric:

5: Meets all criteria; consistently outstanding performance; many courses in curriculum provide 5 level contributions
4: Meets most criteria; exceeds standards in most areas; at least three courses in curriculum provide 4 or 5-level contributions
3: Meets at least half the criteria; scores close to established standards; at least one course provides 4 or 5-level contribution
2: Fails more criteria than it meets; at least one area of really poor performance; several courses provide at least 3-level contribution
1: Fails most criteria; poor performance in many areas; no courses offer 3-level contribution.

Outcome a: An ability to apply knowledge of mathematics, science and engineering to building structures and materials				
Direct Measures	Doc	Standard	2016-17 Performance	Meet Standard
Calculus portion of F.E. exam	1	0	+7	Y
Prob and Stats portion of F.E. exam	1	0	0	Y
Statics portion of F.E. exam	1	0	+8	Y
Mech of Materials portion of F.E. exam	1	0	+4	Y
Material Science portion of F.E. exam	1	0	0	Y
ARCE 444 final exams	12/ 13	75.0	79.7	Y
ARCE 412 final exam		75.0		N/A
ARCE 302 final exam	14	75.0	90.5	Y
Indirect Measures		Standard	2016-17 Performance	Meet Standard
Question 1. Senior survey	3	4	4.32	Y
Question 1. Faculty survey	--	4	4.71	Y
Curriculum Measures		Standard	2016-17 Performance	Meet Standard
Completion of ARCE 211/212/223/225/227/302/303/304/305/306 /351/352/353/371/372/412/421/422/444/ 451/452/ 453/ 483	31	5.0	5	Y
Completion of Math 141/142/143/241/244 Physics 131/132/133 Chem 124	--	100%	100%	Y
2016-17 Assessment: 5				

Table 6: Results of Outcome 3a for the 2016-17 Academic Year assessment

Outcome 3a received a score of 5 because almost all criteria are met and a substantial portion of the curriculum contributes highly to this outcome. Some of the criteria were met in an overwhelming fashion. This in an important step that many programs neglect. By reporting a final score, the program is not leaving it to the ABET evaluator to interpret the data and draw the conclusion. The same tables can be created for the new Criterion 3 Student Outcomes. Table 7 shows one such example for Outcome 4. The assessment is not yet complete because the data collection for AY 17-18 is still ongoing.

The consolidated results for Student Outcome 3 (a)-(k) assessment are shown in Table 8. These results can be compared to the previous six years so that trends can be observed. These results can be used for making decisions in the continuous improvement process. With the new Criterion 3 outcomes, the Table 8 will start over as the AY 17-18 assessment is completed and it will start a new historical record. This demonstrates an advantage of switching to the new criteria now. There will be a three-year historical record under the new criteria when this program is next evaluated in 2020.

Outcome 4: Communicate effectively with a range of audiences.				
Direct Measures	Doc	Standard	2017-18 Performance	Met Standard
Graduate writing requirement		100%		
Senior project presentations		4		
ARCE 257 project grade		75%		
ARCE 452 drawing package		75%		
ARCE 260 writing assignment		75%		
ARCE 444 concrete lab		75%		
ARCE 415 presentations – oral/visual		75%		
ARCE 224 design of experiment presentations		75%		
Indirect Measures		Standard	2017-18 Performance	Met Standard
Question 7. Senior survey (graphical)		4		
Question 8. Senior survey (writing)		4		
Question 9. Senior survey (speaking)		4		
Question 7. Faculty survey (graphical)		4		
Question 8. Faculty survey (writing)		4		
Question 9. Faculty survey (speaking)		4		
Curriculum Measures				
Completion of CM115 and ARCE 371/372/451/452/453		4.38	4	N
Completion of Area A1 Expository Writing, A2 Oral Communication, A3 Reasoning/ Argumentation/Writing and C1 Literature	--	100%	100%	100%
2017-18 Assessment:				

Table 7: Outcome Assessment for new ABET Student Outcome 4 (in progress)

Conclusions

After substantial public comment, the revised ABET criteria 3 (Student Outcomes) and 5 (Curriculum) of the general criteria have been approved and will go into effect in the 2019-2020 evaluation cycle. The good news for current programs is that the changes are minor and as this paper demonstrates, it will be relatively easy to incorporate these new standards for accreditation into existing program assessment systems. The potential bad news for profession is that changes to the ABET general criteria are difficult and occur only once per several decades. Because the changes were so minor, an opportunity for needed change may have been missed.

#	Assessment of Outcomes: Summary	09-10	10-11	11-12	12-13	13-14	15-16	16-17
a	Apply knowledge of mathematics, science and engineering to building structures	4	4	4	5	5	5	5
b	Design & conduct experiments, analyze and interpret data	4	4	4	4+	3+	4	4+
c	Design a building system, component, or process to meet desired needs within realistic constraints	4+	4+	4+	4+	5	5	5
d	Function in interdisciplinary teams for the design and construction of buildings	4	4	4	4+	4+	3+	4-
e	Identify, formulate and solve structural engineering problems	4+	4+	4+	5	5	4+	5
f	Understanding of professional and ethical responsibility	3	3	3+	3+	3	2+	3-
g	Ability to communicate effectively	3	3	3	3	3+	4-	3+
h	Understand engineering in a global and societal context	3+	4	4	4	4+	3-	3
i	Ability to engage in life-long learning.	4-	4	4+	4+	4	3+	3+
j	Demonstrate knowledge of contemporary issues related to built environment	3+	4	4	4-	4	2+	3-
k	Use the techniques, skills and tools necessary for structural engineering practice	4	4	4+	5	5	4+	4
l	Application of construction and constructability issues in buildings	4-	4	4	4	5	4+	4-

Table 8: Consolidated assessment results of program outcomes for the 2016-17 ARCE program assessment

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