Lessons Learned: Adoption of ASCE BOK3 Student Outcomes Consistent with ABET 1-7

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Lessons Learned: Adoption of ASCE BOK3 Student Outcomes Consistent with ABET 1-7

Abstract:
Following its fall 2018 ABET visit, the Rose-Hulman Institute of Technology's Department of Civil and Environmental Engineering identified the coming release of ASCE BOK3 and the new ABET 1-7 student outcomes as an opportunity to review and revise their program's student outcomes. All of the faculty members took part in the process of identifying the fit of the BOK3 outcomes with ABET 1-7, ABET civil engineering program criteria, and institute student outcomes. The result was 22 different program student outcomes requiring assessment activity and documentation.

This paper summarizes what we have learned over the past six years and what we recommend and plan in our continuous improvement process going forward. Our recommendation continues to follow BOK3 but realistically addresses the removal of some unnecessary program student outcomes along with realignment of outcomes to allow reduced overhead meeting ABET 1-7.

Selecting New Outcomes

Background

The Rose-Hulman Institute of Technology's Department of Civil and Environmental Engineering completed an ABET visit in the fall of 2018. At that time, ABET required that a program's student outcomes address eleven outcomes referred to as a-k. However, the Engineering Accreditation Commission of ABET, EAC, had already indicated that it would be changing Criterion 3-Student Outcomes for engineering programs starting with the 2019-2020 academic year. The new required student outcomes are often referred to as ABET 1-7 (Table 1).

At the same time, ASCE's Civil Engineering Body of Knowledge 3 Task Committee was working on its update to the Body of Knowledge, BOK3, representing a list of "knowledge, skills and attitudes necessary for entry into the practice of civil engineering at the professional level" (ASCE 2019). The result was a list of 21 outcomes that should be addressed at the undergraduate level (Table 2). Note that some of those outcomes have both cognitive and affective domain expectations.

With the upcoming changes in the ABET requirements and updates to the ASCE Body of Knowledge, we decided it was the ideal time to take a fresh look at our program's student outcomes. The process we followed to develop student outcomes that address both ABET requirements and the BOK3 is described in detail in a previous ASEE paper (Sutterer *et al* 2019).

Table 1. ABET Student Outcomes 1-7 (ABET 2019).

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

Table 2. ASCE Body of Knowledge Student Outcomes (ASCE 2019).

BOK3 Student Outcome	Cognitive	Affective
1. Mathematics	✓	
2. Natural Sciences	✓	
3. Social Sciences	✓	
4. Humanities	✓	
5. Materials Science	✓	
6. Engineering Mechanics	✓	
7. Experimental Methods	✓	
8. Critical Thinking and Problem Solving	✓	
9. Project Management	✓	
10. Engineering Economics	✓	
11. Risk and Uncertainty	✓	
12. Breadth in Civil Engineering	✓	
13. Design	✓	
14. Depth in a Civil Engineering Area	✓	
15. Sustainability	✓	✓
16. Communication	✓	✓
17. Teamwork and Leadership	✓	✓
18. Lifelong Learning	✓	✓
19. Professional Attitudes	✓	✓
20. Professional Responsibilities	✓	✓
21. Ethical Responsibilities	✓	✓

Outcomes Adopted

The Department largely followed the format of the BOK3, but merged some topics and expanded others. Fundamentally, we believed that the BOK3 expressed all of the ABET 1-7 student outcomes but in a simplified way since topics are each given their own outcome rather than strung together. We believed that expressing the student outcomes in this expanded format would provide more detailed information to guide continuous improvement efforts.

Each outcome had at least one uniquely crafted outcome criterion. For some outcomes, we decided that the topic was too broad and thus created multiple criteria below the outcome. For some outcomes, we were unsure of how well our students might perform and decided to create multiple outcome criteria at different cognitive levels to help us investigate performance. In addition, we added one student outcome beyond both ABET 1-7 and the BOK3: Service. The result was 22 outcomes with 45 supporting outcome criteria (Appendix A).

Seven of the BOK3 Student Outcomes (Table 2) have both cognitive and affective components. In some cases, such as Sustainability and Communication, we chose to have a blend of Student Outcome Criteria that address both the cognitive and affective aspects. For some, like Teamwork and Leadership, we adopted Student Outcome Criteria that only address affective aspects. Our reasoning was that if a student effectively demonstrates the affective behaviors, they implicitly have sufficient command of the cognitive learning.

Once we adopted the program student outcomes and outcome criteria, we developed Primary Traits for each outcome criterion. Those traits are the attributes that a student artifact must demonstrate for the artifact to be deemed as passing the outcome criterion.

Lessons Learned

Programs Don't Have to Adopt ABET 1-7 Directly

The *Criteria for Accrediting Engineering Programs* document by the Engineering Accreditation Commission specifically states under I. General Criteria for Baccalaureate Level Programs, Criterion 3. Student Outcomes, that "Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program" (ABET 2024a). That has led many programs and many Program Evaluators (PEVs) to interpret the requirement to be to adopt ABET 1-7 verbatim.

The *ABET Self-Study Questionnaire: Template for a Self-Study Report* (ABET 2024b), however, states under Criterion 3.A. Student Outcomes, that "In the event that a program has not stated any student outcome verbatim as cited in the Engineering Accreditation Criteria, all elements required by that outcome must be

retained." This clarifies that programs can adopt criteria in a format that best serves their continuous improvement process as long as all of the elements of ABET Student Outcomes 1-7 are incorporated.

Granularity in Assessment Can Help Continuous Improvement
When we adopted our Program Student Outcomes in 2019, many were new for us so we had no data on how well our students might perform. We selected the cognitive and affective levels we wanted our students to attain to match or exceed the BOK3 recommended Levels of Achievement. The Levels of Achievement in the BOK3 document represent levels in Bloom's taxonomy for the cognitive domain (Bloom *et al* 1956) and the affective domain (Krathwohl *et al* 1964). Performance at a higher level implicitly assumes ability in the lower levels as well.

Since we were unsure whether our program was achieving the chosen Levels, we developed Outcome Criteria at different Levels of Achievement for some of the Program Student Outcomes. By assessing the different Levels from the start, we would know the actual Level of Achievement of our students rather than just knowing how many reached the target Level of Achievement. For continuous improvement, we wanted to know what our program was achieving so we could make informed decisions on changes to help our students get to the target level.

An alternate approach would have been to start with assessment only at the target Level of Achievement. For those Student Outcomes that do not adequately meet the target level, we could then identify lower Level of Achievement criteria, gather data, and determine what level our program is actually achieving. That approach would likely have added a one-year delay in the continuous improvement cycle. We did not want to lose that much time as we endeavored for our students to achieve the full Body of Knowledge in our program.

Ensuring ABET 1-7 Coverage
According to the *ABET Self-Study Questionnaire* (ABET 2024b), "…all elements required by that [ABET Student Outcome] must be retained. Further, the program must not alter the intent or otherwise diminish the meaning of that outcome." As we prepared for our 2024 ABET visit, we interpreted this requirement to mean that every component of an ABET Student Outcome must be demonstrated simultaneously. By that we mean that every component be demonstrated by the same activity in the curriculum.

When we developed the original 22 program student outcomes and supporting criteria, we were careful to ensure that we had covered all aspects of ABET 1-7 student outcomes. However, we were not careful to ensure that all aspects were demonstrated in one academic experience (e.g., a term project, one homework assignment). For example, ABET Student Outcome 4 is "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." We were assessing ability to make ethical decisions in a different context than where we were assessing ability to consider the impact of engineering solutions in global, economic, environmental, and societal contexts.

As a result of this review process, we adopted two new student outcome criteria: 20.4 and 21.3. These additional student outcome criteria ensured that the skill was being demonstrated in the context specified by ABET Student Outcomes 1-7. We also observed that we were using the same activity (e.g., capstone design project) to provide the artifacts for each of the program student outcome criteria demonstrating a single ABET student outcome, but using that particular activity was not a requirement in our process. Because we felt it necessary to demonstrate that all aspects of the ABET student outcome were demonstrated in one academic experience, we also updated the Primary Traits of several criteria to ensure that the source activity was explicit. Appendix B contains the details of which Outcome Criteria were used to demonstrate each ABET Student Outcome.

Workload

We willingly and intentionally chose to have 22 program student outcomes and 45 student outcome criteria so that we could have granularity in our assessment data to inform curriculum change decisions. As an example, that granularity was helpful as we decided curriculum changes to improve performance in our Program Student Outcome 6. Experimental Methods and Data Analysis. Each quarter we met as a department for a half day to review the status of artifact gathering, assessment of the artifacts, and any proposed changes based on student performance.

We typically gathered one round of artifacts for each student outcome criterion every year and assessed those artifacts annually. Each of the nine faculty in the department contributed to the assessment process in order to distribute the workload. Most of the assessments occurred during the summer, and each faculty member dedicated several days' worth of effort to complete their portion. Between the meetings each term and individual time assessing student work, the department invested roughly 250 hours per year. That translates to each member of the department spending approximately one half hour each week of the year on continuous improvement.

Results

Based on five years of assessment of the 22 program student outcomes, we observed the following results:

- 15 Program student outcomes consistently met or exceeded our goals
- 4 Program student outcomes occasionally fell below our goal levels
- 3 Program student outcomes frequently failed to meet our goals

The program student outcomes that occasionally fell below our goal levels were often remedied by adjustments to the assignment wording so that it better matched the Primary Traits of the student outcome criterion. In those cases, the continuous improvement process did not improve our curriculum but rather improved the assessment instrument. We did identify three areas that we wanted to improve and made curriculum changes to improve student performance in each.

We have concluded that the extensive effort over that sustained period of time was helpful to conclude that our program is solid in achieving most of its goals with respect to the ASCE Body of Knowledge. However, we have also concluded that continuing that effort, considering what we already know, would not be worthwhile.

Demonstrating Program Criteria

The EAC of ABET requires the same eight General Criteria for all baccalaureate level programs. In addition, it requires Program Criteria specific to the academic program. For Civil and similarly named programs, the program criteria are set by an ASCE committee. During the 2018-2019 review cycle, the Program Criteria for Civil and Similarly Named Engineering Programs reflected many of the topics covered by the BOK3 but missing from ABET Student Outcomes 1-7. For the 2024-2025 review cycle, the Civil Program Criteria were modified slightly.

The program criteria are topics that must be covered in the curriculum, but need not be assessed for ABET accreditation. Because we adopted program student outcomes that addressed all of BOK3, we chose to assess student performance for most of the Civil Program Criteria. An auxiliary benefit of that decision is that we were able clearly demonstrate that our curriculum addressed most of the Civil Program Criteria through the artifacts gathered for assessment of relevant program student outcomes. For the remaining requirements, we still needed to identify where in the curriculum the specific requirement was being addressed.

Next Iteration

To focus our efforts on continuous improvement, we have chosen to streamline our accountability process. We are planning to adopt ABET Student Outcomes 1-7 as written for our next assessment cycle. Many of those student outcomes are areas of strength, so one goal is to minimize the assessment overhead for those student outcomes. That will allow us to focus our efforts on improving in areas that are not at the level we want for our graduates.

Rather than dilute our efforts by assessing all the BOK3 outcomes, we have decided as a department to focus on just a few key areas in addition to ABET 1-7 student outcomes moving forward. The tentative wording of those proposed additional Program Student Outcomes is the following:

8. Intercultural Engagement: Engage with diverse beliefs, cultures, languages, or societies.
9. Service: Partner with a community to create positive change.

We have chosen areas that we find aspirational, so student performance is likely to be below our goal level for a while as we work on curricular changes to target those aspirational program student outcomes. Those target program student outcomes are primarily in the affective domain.

ASCE is beginning to develop the next edition of the Body of Knowledge. Our intent is to ensure that our curriculum addresses all of the student outcomes covered in the new BOK once it becomes available. However, we have decided against assessing all of them.

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Appendix A: Program Student Outcomes and Supporting Criteria

1. Mathematics: Apply mathematics, including differential equations and numerical methods, to solve engineering problems.
   1.1 Solve an engineering problem using an appropriate level of mathematics
2. Science: Apply principles of natural science to solve engineering problems.
   2.1 Apply knowledge from the natural sciences that contributes a significant role in the solution of an engineering problem
3. Social Sciences and Humanities: Apply concepts and principles developed from humanities and social sciences to inform engineering design.
   3.1 Use critical empathic skills to analyze stakeholder perspectives and use that information to inform decision making.
4. Materials Science: Apply concepts and principles of materials science to solve civil engineering problems.
   4.1 Apply knowledge of materials science to the solution of engineering problems.
5. Engineering Mechanics: Apply concepts and principles of solid and fluid mechanics to solve engineering problems.
   5.1 Apply knowledge of solid and fluid mechanics to the solution of engineering problems.
6. Experimental Methods and Data Analysis: Develop and conduct civil engineering experiments in at least two technical areas, analyze and interpret experimental data, and use engineering judgement to draw conclusions.
   6.1 Develop and conduct an experiment or experimental program to obtain the data needed to make an engineering decision
   6.2 Evaluate the implication of results from a civil engineering experiment
7. Critical Thinking and Problem Solving: Use critical thinking to formulate an effective solution to a civil engineering problem.
   7.1 Formulates high-quality, evidence-based conclusions to questions, problems, or issues.
   7.2 Critically examines the claims of others and articulates opinions in support or opposition.
   7.3 Given an open-ended question or problem, discusses the problem constraints or contextual factors (ethical, cultural, and/or social) of the problem using appropriate evidence.
   7.4 Develops a solution to an open-ended problem.
8. Project Management: Apply concepts and principles of project management in the practice of civil engineering.
   8.1 Explain key concepts in project management.
   8.2 Develop at least one solution to a project management problem.
9. Engineering Economics: Apply engineering economics concepts and principles to make engineering decisions.
   9.1 Determine the best option for an engineering decision based on economic analysis.

10. Risk and Uncertainty: Apply concepts and principles of probability and statistics to address uncertainty and risk relevant to civil engineering.
    10.1 Apply the concepts of probability and statistics to quantify uncertainty in a civil engineering context.
    10.2 Describe how the quantitative measure of uncertainty influences an engineering design.
11. Breadth in Civil Engineering Areas: Apply concepts and principles to solve problems in at least four technical areas appropriate to civil engineering.
    11.1 Apply discipline-specific knowledge to solve civil engineering problems
    11.2 Display breadth in discipline-specific problem-solving skills (four technical areas)
12. Design: Apply an engineering design process to complex engineering problems in more than one civil engineering technical area.
    12.1 Develop design objectives that address client needs and are technically feasible
    12.2 Create and evaluate design options by applying the engineering design process.
    12.3 Design a system, component, or process for a complex civil engineering problem by applying principles of engineering, science, and mathematics
13. Technical Depth: Apply advanced concepts and principles to solve engineering problems.
    13.1 Apply advanced concepts and principles learned in CE elective courses to solve engineering problems.
14. Sustainability: Apply principles of sustainability in the solution of civil engineering problems.
    14.1 Explain potential impacts of civil engineering projects in economic, environmental, and societal contexts.
    14.2 Apply engineering design to produce a solution that meets specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
    14.3 Analyze the sustainable performance of civil engineering projects from a systems perspective.
15. Communication: Prepare and present technical content to both specialized and general audiences in an effective manner within verbal, written, and graphical formats.
    15.1 Presents a coherent argument supported by evidence.
    15.2 Demonstrates an understanding of the needs of a non-specialized audience and the ability to adapt information to that audience.
    15.3 Uses appropriate, relevant, truthful, and compelling visual content to illustrate proficiency of a subject.
16. Leadership: Apply leadership concepts and principles to direct the efforts of a small group.
    16.1 Use a leadership approach to motivate a group.
    16.2 Use leadership to effectively motivate a group to meet objectives.

17. Teamwork: Function effectively as a member of a team.
    17.1 Demonstrates that the team environment is collaborative, supportive and inclusive.
    17.2 Use the team's diversity to meet the team's objectives.
    17.3 Effectively manage a team by establishing goals, defining objectives, and planning tasks to meet the objectives.
18. Lifelong Learning: Acquire and apply new knowledge as needed, using appropriate learning strategies.
    18.1 Participate in life-long learning activities.
    18.2 Locates, evaluates and applies required information to the problem at hand.
19. Professional Attitudes: Practice professional attitudes relevant to the practice of engineering.
    19.1 Practice professional attitudes including integrity, dependability, consideration of others, and flexibility relevant to the practice of civil engineering.
20. Professional Responsibilities: Explain professional expectations relevant to the practice of civil engineering.
    20.1 Describe how a civil engineering design has considered health and safety.
    20.2 Discuss a situation where legal concerns would affect the design or implementation of a civil engineering project.
    20.3 Demonstrate the importance of professional licensure.
    20.4 Recognize professional responsibilities in engineering situations.
21. Ethical Responsibilities: Analyze ethical dilemmas involving conflicting ethical interests to recommend and justify a course of action.
    21.1 Determine possible courses of action to ethical dilemmas involving conflicting ethical interests.
    21.2 Justify an appropriate course of action to an ethical dilemma involving conflicting ethical interests.
    21.3 Recognize and meet ethical responsibilities when making engineering judgements.
22. Service: Demonstrate a commitment to service to the community as a civil engineer.
    22.1 Demonstrates a commitment to service to the community.
    22.2 Demonstrates a personal contribution to a community challenge that reflects on skills used, relationships made (with stakeholders), and actions taken to solve that community challenge.

Appendix B: Mapping of Program Student Outcomes to ABET 1-7

ABET student outcome (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Satisfied by:
Program student outcome (12) Design: Apply an engineering design process to complex engineering problems in more than one civil engineering technical area.

Specifically
Criterion (12.3) Design a system, component, or process for a complex civil engineering problem by applying principles of engineering, science, and mathematics.

Note: We define "design" as requiring the identification of a need, formulation of the problem statement, and development of a solution. These three elements are required traits of the artifacts. Also, one of the required traits of artifacts for this criterion is that the problem must have no obvious solution, thus demonstrating complex.

ABET student outcome (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.

Satisfied by:
Program student outcome (14) Sustainability: Apply principles of sustainability in the solution of civil engineering problems.

Specifically
Criterion (14.2) 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.

ABET student outcome (3) an ability to communicate effectively with a range of audiences.

Satisfied by:
Program student outcome (15) Communication: Prepare and present technical content to both specialized and general audiences in an effective manner within verbal, written, and graphical formats.

ABET student outcome (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.

Satisfied by a collection of five criteria from our program student outcomes. To ensure that the ABET outcome is demonstrated coherently, each of the five criteria require that the artifact come from senior design and be related to the capstone design project.

Program student outcome (21) Ethical Responsibilities: Analyze ethical dilemmas involving conflicting ethical interests to recommend and justify a course of action.

Specifically
Criterion (21.3) Recognize and meet ethical responsibilities when making engineering judgements.

Program student outcome (20) Professional Responsibilities: Explain professional expectations relevant to the practice of civil engineering.

Specifically
Criterion (20.4) Recognize professional responsibilities in engineering situations.

Program student outcome (7) Critical Thinking and Problem Solving: Use critical thinking to formulate an effective solution to a civil engineering problem.

Specifically
Criterion (7.3) Given an open-ended question or problem, discusses the problem constraints or contextual factors (ethical, cultural, and/or social) of the problem using appropriate evidence.

Criterion (7.4) Develops a solution to an open-ended problem.

Program student outcome (14) Sustainability: Apply principles of sustainability in the solution of civil engineering problems.

Specifically
Criterion (14.1) Explain potential impacts of civil engineering projects in economic, environmental, and societal contexts.

ABET student outcome (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.

Satisfied by a collection of three criteria from our program student outcomes. To ensure that the ABET outcome is demonstrated coherently, each of the three

criteria require that the artifact come from senior design and be related to the capstone design project.

Program student outcome (17) Teamwork: Function effectively as a member of a team.

Specifically
Criterion (17.1) Demonstrates that the team environment is collaborative, supportive and inclusive.

Criterion (17.3) Effectively manage a team by establishing goals, defining objectives, and planning tasks to meet the objectives.

Program student outcome (16) Leadership: Apply leadership concepts and principles to direct the efforts of a small group.

Specifically
Criterion (16.2) Use leadership to effectively motivate a group to meet objectives.

ABET student outcome (6) an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

Satisfied by:
Program student outcome (6) Experimental Methods and Data Analysis: Develop and conduct civil engineering experiments in at least two technical areas, analyze and interpret experimental data, and use engineering judgement to draw conclusions.

ABET student outcome (7) an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Satisfied by:
Program student outcome (18) Lifelong Learning: Acquire and apply new knowledge as needed, using appropriate learning strategies.