Methodology for Increased Assessment Resolution for ABET Outcomes

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Abstract

ABET requires continuous improvement of programs based on the results of program-level assessment of ABET Criterion 3 Student Outcomes (SO). Based on observations by one of the authors during more than 20 years as an ABET Program Evaluator and/or Team Chair, programs engaged in the assessment process often encounter challenges in the areas of sufficiency, consistency, and efficiency. In terms of sufficiency, programs may be cited for shortcomings due to inadequate assessment of *each element* of a given SO. In terms of consistency, programs may lack a meaningful systematic process for determining *program-level* assessment of the SOs to be used for *program-level* continuous improvement and may also struggle to support faculty in the development of appropriate assessment tools that dovetail with the respective curricular and pedagogical approaches of individual faculty. Finally, in terms of efficiency, while it is possible for programs to collect assessment data effectively, it may have come at the cost of an unnecessarily overburdened faculty that may struggle to understand ABET assessment and more specifically, what is needed from them.

In this paper we present a holistic, systematic methodology that allows programs to design a higher resolution assessment process that places more minimal and more clearer requirements on faculty that allows assessment committees to compile program-level metrics easily from myriad assessment tools provided by faculty. The methodology revolves around an initial faculty assessment tool template that *efficiently* helps faculty understand SO assessment and how to choose an effective assessment tool. This is then followed by a faculty assessment rubric in the form of an Excel scorecard provided to the faculty for scoring their assessment tool. Excel scorecards from all faculty are collected by the program, and the process concludes with an easy compilation of data from many courses and faculty for program-level assessment. The methodology was first developed for the Virginia Tech Mechanical Engineering (VTME) program that is a large program (70 faculty and 1166 students) in an R1 research institute. The new approach significantly contributed to a successful 2025 ABET review with no shortcomings. It is expected that the methodology is general enough that it will be easily applicable to programs of all types and sizes, including smaller engineering programs. Anecdotal evidence indicates that faculty appreciate how the approach is clear and straightforward and helps them better understand both ABET SO assessment and what the program needs from them in an efficient manner.

1 Introduction

ABET accreditation follows a structured review process conducted on a defined cycle, typically every six years, during which programs demonstrate compliance through a comprehensive selfstudy report, an on-site evaluation, and a formal due process review [1]. ABET, as well as our program, place strong emphasis on continuous improvement based on program-level assessment as an ongoing activity throughout the accreditation cycle. ABET does not prescribe specific tools, program indicators, or methods for assessment and evaluation. Instead, it provides programs with the flexibility to design and implement assessment processes that best align with their mission, curriculum, and institutional context. Programs often struggle working with myriad faculty on the development of appropriate and useful assessment tools, as well as collecting and compiling data to determine program-level attainment of each SO as described in Criterion 3, followed by program continuous improvement based on this collected assessment data as described in Criterion 4. Additionally, programs often overlook the need to assess each element of an SO that can potentially result in shortcomings during an ABET review, resulting in additional work for a program.

In this paper, we present a holistic, systematic methodology that allows programs to easily perform a higher resolution assessment process that is more efficient for both individual faculty, and for programs as a whole in obtaining program-level assessment for each SO. This methodology, centered first around a short but comprehensive faculty template, helps faculty efficiently understand ABET assessment requirements so that they can quickly identify an *appropriate* assessment tool (or tools) from their course (such as a final exam problem, test problem, laboratory report, etc.) to fully evaluate the attainment of all elements of an SO. The next step in the methodology is to provide faculty with an Excel scorecard spreadsheet that requires them to assess student performance on a 1-3 score for each SO element for their identified assessment tool for a subset of students (determined statistically and randomly). The methodology then allows for easy collection of data in a consistent format from myriad courses and faculty that allows the program to easily compile all individual Excel scorecards into program-level measures of attainment of each element of all SOs.

In this methodology, the faculty are selecting concrete measurable actions that students should be able to perform in their course, often referred to as program indicators [3]. Since programs decide which courses are used for which SO assessment, and since each assessment tool identified by faculty is broken down into course-level indicators and reviewed by the program assessment committee, these individual course-level indicators are also valid program-level indicators. Anecdotal evidence indicates that faculty appreciate how the approach is clear and straightforward and helps them better understand both ABET SO assessment and what the program needs from them in an efficient manner. We describe the new methodology here in an effort to facilitate the adoption of our approach by other institutions and programs that see this as an opportunity to improve sufficiency, consistency, and efficiency in their continuous improvement process. This paper includes a background section including basic info on the ABET General Criteria C3 and C4, typical challenges faced by programs, brief information on our program's prior SO assessment approach for context, and motivation for the development of the new approach. This section is followed by a New Methodology section covering each aspect of the new increased-resolution methodology and its implementation, including examples. The paper ends with a Conclusions and Recommendations section.

2 Background

2.1 ABET summary

All engineering programs seeking accreditation from the Engineering Accreditation Commission (EAC) of ABET must show that they meet the General Criteria for Baccalaureate Level Programs. ABET establishes clear accreditation criteria that form the basis for all program reviews [1]. Specifically, there are eight ABET General Criteria that define the minimum standards programs must meet: (1) Students, (2) Program Educational Objectives, (3) Student Outcomes (SOs), (4) Continuous Improvement, (5) Curriculum, (6) Faculty, (7) Facilities, and (8) Institutional Support [2].

In this paper, we focus on Criterion 4, Continuous Improvement, with an emphasis on collecting and compiling assessment data for the meaningful evaluation of the level of attainment of each of the seven SOs listed in Criterion 3 at the program level. We will refer to individual SOs in Criterion 3 as C3-1, C3-2, etc. These ABET outcomes describe what students should know and be able to do when they graduate.

2.2 Common program challenges in C3/C4 ABET accreditation

Note that Criterion 4 focuses specifically on appropriate systematic documented processes used by a program to measure what extent that Student Outcomes are being attained at the *program level* and how this assessment data is used to inform *program-level* continuous improvement. Historically, some programs struggle to determine appropriate assessment tools and collect data at the curricular level that translate into meaningful program-level assessment for measuring the attainment of SOs by their students. Programs sometimes fall back on course-level only assessment and associated continuous improvement actions that result in shortcomings during the ABET review. This is because the course-level only feedback loop scenarios are not based on program-level attainment of SOs and making associated actions based on the program-level data. In other words, there is a difference between looking at holistic program-level assessment data and basing an action by the program to make a change in a single course, and looking only at course-level assessment data and making a change in that course based on that data only. While both scenarios are meaningful, only the former represents program-level evaluation and meets the ABET C4 requirements. Additionally, programs sometimes neglect to effectively assess all elements in a C3 SO, which can also result in a shortcoming. For example, the C3-6 SO is described as “an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions.” If programs focus on the “conduct appropriate experimentation, analyze and interpret data” aspects, but neglect to measure a student's ability to "develop experimentation" or "use engineering judgement to draw conclusions," a potential shortcoming can arise during the ABET review.

Additionally, almost all programs, but particularly large R1 engineering programs, struggle with developing a meaningful and efficient systematic approach for working with many different faculty instructing in different courses. Faculty that are not regularly involved with ABET year-to-year may struggle to understand the ABET C3 and C4 requirements and how to support program-level assessment and continuous improvement in the ABET context. Programs also struggle on how to engage faculty but not overburden them. Unfortunately, without a methodical, efficient, and effective approach to program-level assessment and continuous improvement, programs inadvertently create extra work for faculty and/or obtain shortcomings during ABET accreditation review that require considerable follow-up work. The new methodology described in this paper provides programs with a thorough and efficient approach for avoiding this when implemented correctly.

2.3 Previous VTME SO assessment approach from 2019 review

To provide a context for the new methodology, it will be helpful to briefly explain some main aspects of our previous approach for obtaining assessment data for measuring the attainment of C3 SOs. This previous approach was appropriate for the ABET criteria in place at that time, and we successfully passed our ABET review in 2019 with no shortcomings. The essence of the approach was looking at the percentage of students in our program that met or exceeded target scores on assessment tools for each SO. As a program we determined that a minimum of 70% of students meeting or exceeding minimum acceptable scores on assessment tools demonstrated successful attainment of an SO.

Our institution is a large Land Grant R1 institution with an AY2024-2025 Mechanical Engineering enrollment of 1166 students and a faculty size of 70. Large course enrollments in core courses are a common occurrence and, thus, many courses are taught by different instructors over multiple sections.

Our 2019 assessment process included significant effort in creating an appropriate assessment approach, such as designing for statistical significance, timing, reviews of faculty input, determining metrics for attainment of SOs, and logistics of obtaining and reviewing data, among other steps that are not included here for brevity. We focus only on the general operation of how we worked with faculty to obtain assessment data for that period ending in the 2019 review.

In the 2019 approach our program's Assessment Committee (AC) determined which courses would be used for obtaining assessment data for each SO, and then asked faculty teaching in those courses to provide an assessment tool of their choosing for their assigned SO. These faculty each had to provide information to four prompts:

1. *What is the name of your assessment tool (such as "final exam prob 2")?*
2. *Briefly explain why your assessment tool appropriately assesses the ABET C3 SO.*
3. *What is the maximum possible score, or assessment metric, for this tool, (such as "25 points")?*
4. *What is your target score, or minimum acceptable assessment metric, that demonstrates attainment (we recommend the equivalent of 70/100 as an indicator of minimum acceptable attainment)?*

After a review of tool information from faculty by the program's AC, faculty were asked to provide the AC with both the total number of students assessed and the number of students who scored at or above their designated target score for minimum attainment. The number-above-target values were summed over all sections of a given course, creating course-level sums (total number of students assessed where also tallied). The course-level sums were combined with sums for all other courses used to assess a given SO to obtain a program-level sum. This resulted in a final program-level metric that was formed by dividing the program-level sum for a given criterion by the total number of assessed students. In percentage form, this program-level score was referred to as the "percent-above-target" metric, or %AT. The %AT represents the percentage of students whose total score met or exceeded the minimum target score on each of the assessment tools for a given SO. The AC committee determined that a program-level %AT of 70% or higher for each SO demonstrated attainment of that student outcome by the program.

2.4 Motivation for the development of the new methodology

While the previous 2019 process provided meaningful information on the extent of program-level SO attainment, the program identified opportunities for improvement as part of our Continuous Improvement process based on the following:

- The prompt to faculty to identify an assessment tool was too general/vague.
- Some faculty struggled to fully understand ABET SOs and what represented an appropriate assessment tool, and this became unnecessarily time consuming for them and the program.
- There was concern that all aspects, or elements, of each SO may not get assessed unless they are explicitly identified.
- There were concerns about inconsistent scoring approaches on assessment tools by faculty.
- A higher resolution of SO attainment information may facilitate more effective continuous improvement actions.
- It would be helpful to streamline the process so it is less burdensome and more sustainable, particularly as different faculty become involved through new hires and faculty service rotation.

In short, the program was motivated to develop a more effective process to improve sufficiency of assessing each element of a given SO, improve consistency in the identification of assessment tools and scoring approach by faculty, and improve efficiency of the process by helping faculty easily and quickly better understand ABET assessment and leading them to more quickly identify appropriate assessment tools within the context of their own pedagogical styles. It was also noted that a more streamlined and straight forward documented approach is more sustainable as different faculty become involved in the program accreditation process.

3 New high-resolution methodology approach

3.1 Overview

In 2023 our institution's ME ABET Committee initiated an effort to develop a revised assessment process based on the observations listed in the previous section of this paper. The new methodology that was developed includes an increased SO assessment resolution, facilitation of a better understanding of ABET assessment for faculty, a new scoring rubric based on a 1-3 scale, and a system that facilitates compilation of all data into course-level (for courses with multiple sections), and ultimately program-level assessment data. *The center of the new methodology is the separation of ABET Criterion 3 SOs into clearly defined "elements."* This is supported by providing instructors with a Faculty Assessment Tool Template that facilitates the efficient identification of tools to assess each element in SO. This approach preserves instructor autonomy by allowing faculty to still choose their own assessment tools, while providing them with more information through guided questions in the template about what is needed. After individual assessment tools are approved by the program's Assessment Committee (AC), faculty are provided with standard Excel scorecard spreadsheets for scoring their respective assessment tools. These spreadsheets all have a common structure that allows assessment data to be combined, compared, and interpreted more effectively at the program level. This results in more meaningful insights into student learning and support for stronger continuous program improvement because of the higher level of resolution of assessment with a measure of attainment for each element of each SO. In the following sub-sections, we describe various aspects of the methodology and provide some examples to support adoption by other programs.

3.2 Decomposition of ABET criterion 3 SOs into individual elements

The first step in applying the revised methodology is the decomposition of SOs into distinct elements that are meaningfully independent for assessing student knowledge and ability. According to ABET [1], "Student outcomes describe what students are expected to know and be able to do by the time of graduation. These relate to the knowledge, skills, and behaviors that students acquire as they progress through the program." ABET lists seven SOs in their General Criteria [1] referred to here as C3-1 through C3-7. For example, looking at the decomposition of C3-1 into elements is as follows:

Criterion C3-1 states that students must demonstrate [1]:

"an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics."

Accordingly, we decompose C3-1 into the following four assessment elements:

- Element 1: Demonstrate an ability to identify, formulate, and solve a complex engineering problem
- Element 2: Demonstrate an ability to apply principles of engineering
- Element 3: Demonstrate an ability to apply principles of science
- Element 4: Demonstrate an ability to apply principles of mathematics

As can be discerned from the above elements, the decomposition is performed in a way that each element represents a single, cohesive cognitive process. This is performed in such a way that the element is void of any redundancy and ambiguity. For C3-1, we chose to group the "*identify,*" *"formulate,"* and *"solve"* functions of the SO into a single measurable element that focuses on the executional aspect of problem solving. (In principle, Element 1 could be further divided into 3 independent, meaningful elements resulting in a total of six C3-1 elements. This choice would be driven by the assessment goals of a given engineering program). The establishment of Elements 1–4 is meant to assess separate cognitive processes. For brevity, the detailed decomposition of the remaining six ABET SOs are presented in Appendix A.1.

Additionally, this approach fits neatly within the context of the use of Program Indicators [3]. According to a document explaining student outcomes and program indicators on the ABET website [3], "Program Indicators identify what concrete actions the student should be able to perform as a result of participation in the program." By breaking out the SO into different elements and using this as a context for the specification of assessment tools, our approach facilitates the clear articulation of the knowledge and skills necessary for mastery of the outcome, which are the program indicators

For illustrative purposes, Figure 1 shows an example comparison of assessment data for C3-1 using the new methodology of assessing each element of the SO vs assessment data collected with our 2019 bulk assessment approach for each SO for program-level results over three semesters individually. Figure 1 shows a much richer picture of the SO level of attainment and allows departments to more precisely determine continuous improvement actions. For example, in Figure 1(a) a "weak" (above "weak" but below "good" level) level of SO attainment in Spring 2025 was measured for both element 2 (E2) in C3-1 (*"an ability to identify, formulate, and solve complex engineering problems by applying engineering"*) and Element 4 (E4) in C3-1 (*"an ability to identify, formulate, and solve complex engineering problems by applying mathematics"*) triggering a review and continuous improvement actions as needed to improve attainment of these elements of this SO in our program.

In contrast, the previous assessment method, shown in Figure 1(b), evaluates the SO in aggregate and would have flagged the entire outcome rather than isolating Element 4 as the source of concern. As a result, the underlying issue may have been obscured, potentially leading to unfocused or misdirected improvement efforts, or even missed opportunities for corrective action. Additional details on the scoring methodology are provided in Section 4.

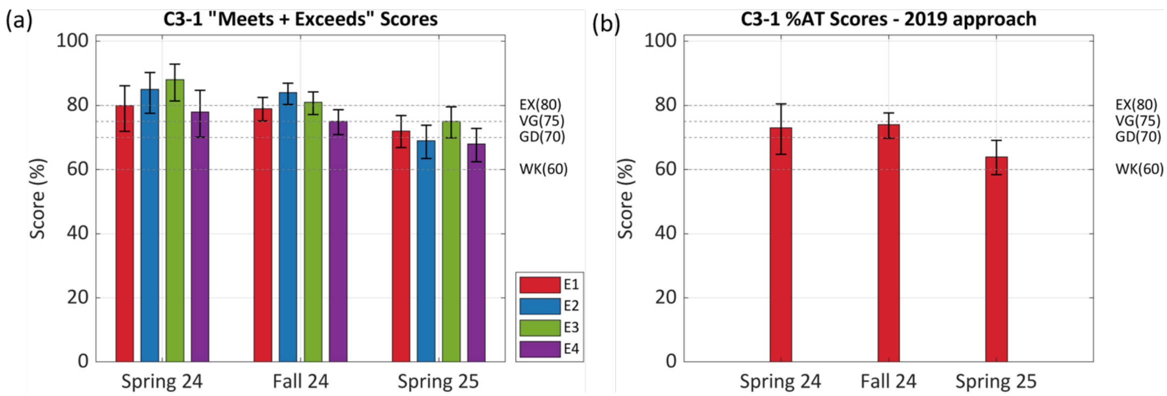

Figure 1. Comparison of ABET C3-1 program-level scores for the revised and former methodologies (E1-E4 represent the four decomposed C3-1 elements): (a) revised method, (b) former method[E1: Identify, formulate, and solve complex engineering problems, E2: Apply principles of engineering, E3: Apply principles of science, E4: Apply principles of mathematics][Attainment thresholds: EX=Excellent, VG=Very Good, GD= Good, WK=Weak]

3.3 Faculty assessment tool template

After decomposing each SO into distinct elements, faculty assessment tool template documents are provided to faculty to aid the creation/selection of effective assessment tools with which to assess their students. The tool template asks the instructor to select one assessment tool for each SO assigned to their course. Examples of acceptable tools include exam problems, project deliverables, lab reports, or other graded assignments that require students to demonstrate the targeted outcomes. The very nature of the approach and questions in the template facilitates quick understanding of assessment needs for faculty who may be new to the process or need a refresher. The questions in the template also act as guided inquiry helping faculty choose better assessment tools for measuring the attainment of each element of an SO.

For example, one question in the C3-1 SO faculty assessment tool template is:

> "*In your assessment tool, how does a student demonstrate that they have an ability to apply principles of engineering to solve the problem?*"

The response from an instructor teaching in a machine design course for their chosen tool was:

> "*they should be able to apply finite element principles, displacement-stiffness and stress-strain relationships to solve the problem.*"

This response is recognized as a performance indicator, and thus, a performance indicator that meets the pedagogical objectives of the instructor emerges as a normal consequence of completing the tool template.

An example of a filled-out tool template is provided in Appendix A.2. for C3-1, which shows how the complete form might be used in a required dynamics systems course for a washing machine vibration problem. The information provided by the faculty member in this example is in blue and italicized. Note that the tool template guides faculty on what an appropriate assessment tool is by having them briefly explain how their chosen tool assesses all elements of the SO. In our experience, some faculty like to provide more than a single assessment tool to insure they are providing our program with clear assessment of all elements in an SO, and this is completely doable in our flexible system. The tool template also guides faculty on how they might want to separate the parts of the problem out for their own grading to make it easier for them to fill out their assessment score for each element in the rubric Excel scorecard spreadsheet they will be provided (described in Section 3.4). While a vibration problem was presented as an example, note that this is a *general* template and can be used in any course that is determined by a program for use in their assessment plan. For brevity, we only discuss the C3-1 tool template, but similar templates were also generated for each of the remaining six SOs with the elements of each SO broken out as shown in Appendix A.1. Collectively, these documents help promote a structured, transparent, and consistent tool generation process that preserves and encourages pedagogic autonomy and flexibility for faculty, while helping them better understand a program's ABET assessment needs in an efficient manner.

3.4 Faculty assessment rubric scorecard in Excel spreadsheet format

After a faculty member submits an appropriate assessment tool to the Assessment Committee (AC), they are provided with a corresponding Excel scorecard spreadsheet, referred to as the *faculty assessment rubric scorecard*. An example scorecard for C3-1 for a mechanical design course is shown in Figure 2. This serves as the primary instrument used by the instructor to record assessment results for individual students within their section. Faculty in each course section assess a sampled group of randomly selected students (determined on a statistical basis by the AC). Each student is assessed using the assessment tool designated by the faculty. For each SO element, faculty enter an assessment score for each student in the sample group using the following three-point scale:

1 = does not meet expectations (DNM)
2 = meets expectations (M)
3 = exceeds expectations (E)

As shown in the example in Figure 2(a), scores for all elements are recorded in the Assessment Rubric Scorecard Excel spreadsheet for each student based on the instructor's assessment of performance on their chosen assessment tool. For clarity and brevity, only a representative subset of the data is presented in Figure 2. This scoring of student performance relative to clearly defined SO elements, and using identical metrics, is one of the distinguishing features of the revised assessment methodology.

Recall that the SO element score is the score associated with the performance indicator established by the instructor for the given SO element, as discussed in Section 3.2. For each SO element, the number of students receiving scores of 1, 2, or 3 is summed at the bottom of the scorecard, as shown in Figure 2. This scorecard process is performed at the section-level for every course selected for ABET Criteria 3 assessment. From this section-level scorecard data, course- and program-level statistics are easily computed.

Note that the use of identical metrics for all assessment tools allow programs to quickly compile data from multiple assessment tools for any SO to determine program-level assessment data. Additionally, the consistent scoring scale allows programs to provide guidelines to "calibrate" faculty scoring, resulting in more consistent scoring across myriad assessment tools. Working with standard Excel spreadsheet templates allows for easy combination of data from myriad instructors, and currently we are able to hire a GTA to support our data collection and management for such a large program. However, this approach lends itself well to online automation, potentially within the context of Canvas or other educational software systems and is a future goal of our program.

It should be noted that in our example in Figure 2 that there is additional information that is extraneous to the application of our approach to other programs. This additional information was used by us for both future reference and for our own evaluation of the new process that included comparison with the previous 2019 assessment approach as described in Section 2.3. This "process comparison data" is shown in Figure 2(c) and 2(d), where Figure 2(c) locates a column in the section scorecard where a student's earned score or grade for the tool, i.e. the "tool score," may be recorded (note, this is not the 1, 2, or 3 assessment score just described, but rather the score that contributes to the calculation of an overall course grade for a student for future reference by the faculty member or AC). Also visible in Figure 2(c) is the maximum tool score assigned by the instructor for the tool (e.g. 100%, 25 pts, etc.). This information is included to enable comparison between the revised element-level assessment approach and the earlier 2019 approach described in Section 2.3, which relied directly on tool scores determined by faculty. This example highlights that element-level aggregation data may exhibit variation, although in some cases it may remain constant.

Rubric For C3-1

Instructions :

1. **Please evaluate the graded assessment tool for each of the students in the spreadsheet in terms of each of the four rubrics. Evaluate each rubric on a scale of 1-3, where 1= Does Not Meet Expectations; 2= Meets Expectations; 3=Exceeds Expectations.**
2. **Please also include the number of maximum points for this assessment tool and add the numerical score of the graded assessment tool for each student in this spreadsheet.**

Please contact ABET coordinator if you have any questions. Thank you for your important help with our ABET accreditation! It is much appreciated.

Course No.and Name	Mechanical Design Course
Instructor Name	Name
Term	Fall 24
Date	4-Dec-2024
Assessment tool name	Problem-2 in Midterm-2
No. of Students sample size	39
Starting Letter	C

Student Outcome C3-1: [Students must demonstrate] an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Maximum score/grade for this Assessment Tool (such as "25 points")		(c) 65	(a)			
Student No.	**Student Name**	**Student Score/Grade for Assessment Tool**	**Element 1** *1=Does Not Meet Expectation; 2=Meets Expectation; 3=Exceeds Expectation*	**Element 2** *1=Does Not Meet Expectation; 2=Meets Expectation; 3=Exceeds Expectation*	**Element 3** *1=Does Not Meet Expectation; 2=Meets Expectation; 3=Exceeds Expectation*	**Element 4** *1=Does Not Meet Expectation; 2=Meets Expectation; 3=Exceeds Expectation*
1	Name #1	57.5	2	2	2	3
2	Name #2	65	3	3	3	3
3	Name #3	25	1	1	1	1
4	Name #4	62.5	3	3	3	3
5	Name #5	65	3	3	3	3
...	Name ...	65	3	3	3	3
35	Name #35	50	2	2	2	2
36	Name #36	62.5	3	3	3	3
37	Name #37	55	2	2	2	2
38	Name #38	65	3	3	3	3
39	Name #39	46	1	1	1	1
(b) Total No. of Students			39	39	39	39
No. of Students Does not Meet Expectation			7	7	7	7
No. of Students Meet Expectation			12	12	12	12
No. of students Exceeds Expectation			20	20	20	20
(d) No. of students above 70%			35			

Figure 2. ABET Faculty Assessment Rubric Scorecard Example for C3-1: (a) Assessment columns for SO elements, (b) Aggregation of number of students based on rubric, (c) "Tool score" (2019 approach), (d) Number of students whose "tool score" exceeded a 70% threshold (2019 approach)

3.5 Course- and program-level aggregation of assessment data

An example of C3-1 course- and program-level scoring is shown in Figure 3. Course-level aggregation is performed using a standardized course-level spreadsheet that compiles assessment data from all sections of a course offered in the same semester as shown in the example in Figure 3. For each section, data are transferred directly from the section faculty assessment rubric Excel scorecard into the course-level spreadsheet. These data include the total number of students assessed (sample size) and values for the number of students who do not meet expectations, who meet expectations, or who exceed expectations for each SO element in the scorecard as shown in Figure 3(a). Also, for comparison with the 2019 approach, the students are separated into an "above target" or "below target" based on their faculty-determined grade or "tool score" as shown in the pink columns in Figure 3a.

(a)

C3-1 Course-Level															
Mechanical Design Course	Element 1			Element 2			Element 3			Element 4			Tool Scores		Total Assessed
	DNM	M	E	DNM	M	E	DNM	M	E	DNM	M	E	# above target	# below target	
Section 1	7	12	20	7	12	20	7	12	20	7	8	24	35	4	39
Section 2	10	27	2	1	38	0	1	38	0	9	30	0	36	3	39
Section 3	12	23	4	5	29	5	6	28	5	9	25	5	37	2	39
Section 4	7	14	14	6	6	23	6	6	23	12	9	14	28	7	35
Total	**36**	**76**	**40**	**19**	**85**	**48**	**20**	**84**	**48**	**37**	**72**	**43**	136	7	152

(b)

C3-1 Program-Level												
Course	Element 1			Element 2			Element 3			Element 4		
	DNM	M	E	DNM	M	E	DNM	M	E	DNM	M	E
Fluid Dynamics	18	53	77	16	71	61	21	66	61	32	59	57
Mechanical Vibrations	46	67	59	39	47	86	50	52	70	48	58	66
Mechanical Design	36	76	40	19	85	48	20	84	48	37	72	43
Total	**100**	**196**	**176**	**74**	**203**	**195**	**91**	**202**	**179**	**117**	**189**	**166**

Legend
DNM = Does not meet expectations
M = Meets expectations
E = Exceeds expectations

Figure 3. Fall 2024 data aggregation tables for C3-1 (a) Course-level table and a (b) Program-level table

Shown in Figure 3(b) is the program-level aggregation, which combines course-level assessment data from all courses selected for SO assessment for C3-1 in Fall 2024. This aggregation produces program-level scores for each SO element, allowing the Assessment Committee and VTME faculty to evaluate overall student performance, identify trends across courses, and support program level decision-making. Traditional %AT scores derived from tool scores are also determined for comparison with earlier assessment cycles used in the 2019 approach, but are not used for program evaluation in the revised process.

From data for each SO element, the program calculates a sum of the number of students meeting expectation plus the number of students exceeding expectation, and then divides this by the total number of assessment samples. This is called the Meets + Exceed score (MES) for each element of each SO, and it is the percentage of students who met or exceeded the acceptable performance level in the assessment tool. Additionally, as shown in Figure 4, the program quantified the level of attainment based on MES scores. The minimum attainment threshold (MES) is established by the Assessment Committee (AC) based on an analysis of historical data. A minimum passing threshold of 70% is adopted, corresponding to a C− grade on the grading scale. Higher levels of attainment are established by the AC to ensure interpretability and to facilitate actionable insights for continuous improvement. The implementation and evaluation of the new methodology is described in detail in Section 4.

Levels	Metric	Attainment
Program	"Meets + Exceeds" Score (MES)	>80% : Excellent
		75-80%: Very Good
		70-75%: Good/Acceptable
		60-69%: Weak
		<60%: Very Weak

Figure 4. Level of Attainment rankings for MES scores.

3.6 Methodology flowchart

To further help explain the approach, a flowchart of the approach is shown in Figure 5. Our process is lead by our program (mechanical engineering) assessment coordinator with support of a full-time GTA, partially dictated by the scale of our program. Programs must still make their own informed decisions in designing their own process and determining details to meet ABET accreditation requirements. However, we do hope that we are providing information to help you make your assessment and continuous improvement processes more sufficient and consistent, while streamlining them for improved efficiency and lower faculty overhead.

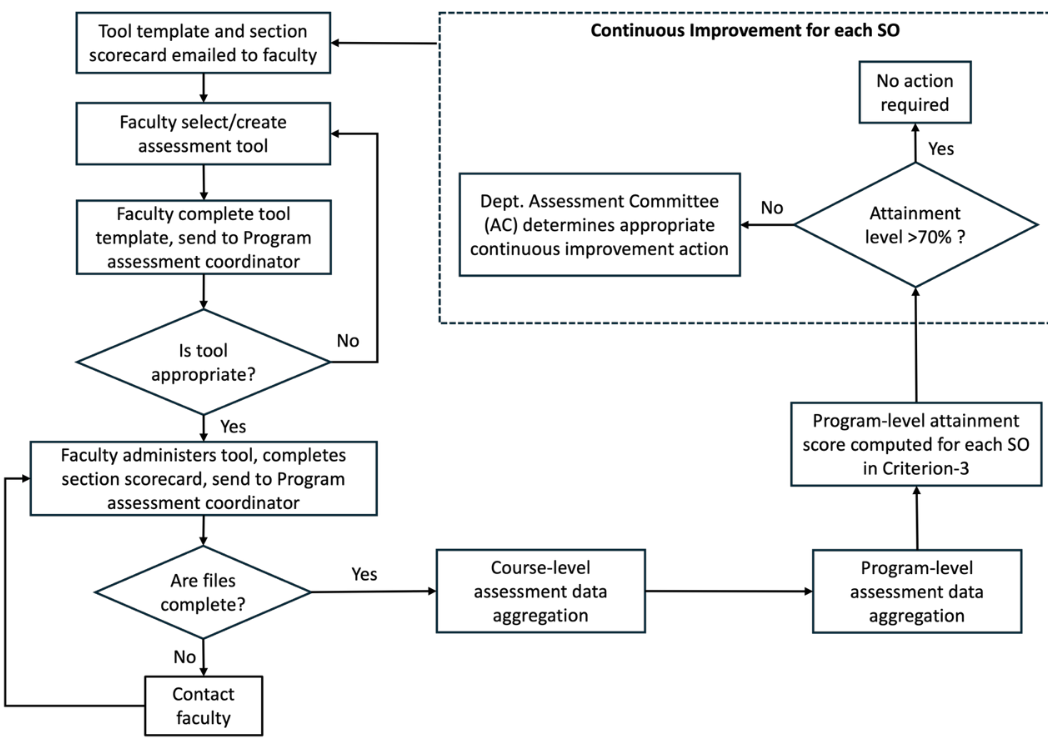

Figure 5. Flowchart of the revised assessment methodology

4 Implementation of the Revised Process and Statistical Sampling Study

4.1 Overview of implementation

The revised assessment process was rolled out in stages across three semesters: Spring 2024, Fall 2024, and Spring 2025. Spring 2024 served as a pilot semester. During this pilot, the goal was to examine the efficacy of the revised assessment process summarized by the flowchart in Figure 5, where faculty assessment tool template, faculty assessment rubric scorecard (Excel spreadsheet), and course- and program-level data analysis tools were fully employed on a limited amount of collected assessment data. Here, formal methods for determining statistical sample sizes were not applied; instead, a fixed sample size of approximately 20 students per section was employed regardless of total section enrollment in Spring 2024. This approach allowed us to focus on the functional mechanics of the new process with only minimal concern for data management challenges.

Full deployment of the revised method occurred in the Fall 2024 and Spring 2025 semesters where data sampling was based on section enrollment statistics per our institution's General Education sampling guidance [4]. Sample sizes were calculated using the following equation (1) *as a planning tool.*

$$\mathrm{n} = \frac{N}{1 + \frac{\varepsilon^2 N}{z^2 \hat{p}(1 - \hat{p})}} \tag{1}$$

where n is the required sample size, N is the population size, z is the z-score corresponding to the desired confidence level, $\hat{p}$ is the population proportion, and ε is the margin of error expressed as a decimal. Per our institution's General Education guidelines [4], a 95% confidence level and a 10% margin of error were assumed. The 95% confidence level corresponds to $z = 1.96$, indicating that if the sampling procedure were repeated many times, approximately 95% of the resulting intervals would contain the true population proportion. The 10% margin of error specifies the maximum permissible deviation between the sample estimate and the true population value, establishing the precision target the sample must satisfy.

The population proportion ($\hat{p}$) represents the true fraction, which is unknown in the planning stage, of the entire population exhibiting the characteristic of interest. The characteristic of interest is the metric MES score used report. For the estimated population proportion $\hat{p}$, the conventional value of 0.50 was adopted. This choice is not a substantive assumption about the underlying population, but rather a conservative mathematical convention: the variance term $\hat{p}(1-\hat{p})$ in equation (1) attains its maximum value of 0.25 at $\hat{p} = 0.50$ and decreases as $\hat{p}$ moves away from this midpoint in either direction. Substituting $\hat{p} = 0.50$ therefore yields the largest sample size the formula can produce for the given confidence level and margin of error, guaranteeing that the resulting n is sufficient regardless of the true population proportion.

Together, these three parameters define the minimum sample size required at the planning stage to achieve the specified precision under the least favorable conditions. Hence, for a class size of 50 students, the equation computes a sample size of 34, while for a class size of 300 students, the computed sample size using equation (1) is 73. The goal of this sampling approach is to generate accurate and meaningful statistics while reducing the assessment burden for instructors.

4.2 Compilation of program-level data

The next stage was the reporting phase of the assessment process, during which aggregated program-level data are communicated to the committee. As described earlier, a simple method is used by faculty for scoring at the assessment-tool level using the 1-3 point scoring metric in each scorecard. This is followed in the process by an aggregation of all data for determining the principal program-level metric, the MES score. Recall that the MES score is calculated from the program-level aggregate data as the sum of the “Meets Expectations” (rubric score of 2) and the “Exceeds Expectations” (rubric score of 3), divided by the total number of samples. For example, for the C3-1 program-level data shown in Figure 3(b) for Element 1 assessment data listed in the bottom row of the table, the Fall 2024 MES score is computed as (196+176) / (100+196+176) = 0.79, or 79%. The Fall 2024 program-level MES scores for all elements of C3-1 are shown in Figure 7.

Recall that in the 2019 approach, a %AT (% Above Target) score was calculated based on the number of students who met or exceeded the numerical grades/scores determined by the Assessment Committee (AC) as minimally acceptable for the specific assessment tool, which the faculty member chose as a general representation of a given SO, and not for each element of an SO. Based on the decision of the AC, the minimum acceptable level of student performance was set at 70% of the numerical score on that tool. The %AT score for that SO was then calculated as %AT = (Number of students at or above the 70% threshold / Total number of students assessed) × 100%. For example, the 74% value shown in Figure 6 indicates that 74% of students assessed scored at or above the 70% threshold on the chosen assessment tool for that SO. Since the numerical tool scores are still collected every semester shown in Figure 3(c), the %AT score can continue to be calculated alongside the new method, allowing direct comparison between the two approaches in each assessed semester. Figure 6 shows this comparison for Fall 2024.

<table>
<tr><th colspan="3">C3-1, Fall 2024</th></tr>
<tr><th>SO Element</th><th>"Meets + Exceeds" Score (MES)</th><th>%AT (70% target)</th></tr>
<tr><td>1</td><td>79%</td><td rowspan="4">74%</td></tr>
<tr><td>2</td><td>84%</td></tr>
<tr><td>3</td><td>81%</td></tr>
<tr><td>4</td><td>75%</td></tr>
</table>

Figure 6. Fall 2024 C3-1 program-level MES scores.

Program-level MES scores are visually presented using bar charts, as illustrated in Figure 1. Each bar represents the aggregated MES score for a given assessment element across all contributing courses for a given semester in Figure 1(a). The comparative %AT scores are represented in Figure 1(b). However, this is not the full picture, as we need to account for the statistical uncertainty due to sampling. This is done through the inclusion of error bars.

The reported results may not fully align with the assumptions made during the statistical planning phase. Error bars are therefore included to indicate the margin of error associated with the sampled data, providing a visual representation of uncertainty in each dataset. The error bars represent 95% confidence intervals computed using the Wilson score method for binomial proportions [4]. The Wilson interval was selected because it provides more accurate coverage than a simple margin-of-error-based approach, particularly for moderate sample sizes and attainment percentages near 100%. Since the reported scores are derived from sampled student populations rather than full censuses, the Wilson interval appropriately captures the sampling uncertainty in the estimated MES proportions [5].

$$p_{low}, p_{high} = \frac{\hat{p} + \frac{z^2}{2n} \pm z\sqrt{\frac{\hat{p}(1-\hat{p})}{n} + \frac{z^2}{4n^2}}}{1 + \frac{z^2}{n}} \tag{2}$$

$$\hat{p} = \frac{x}{n}, \tag{3}$$

$$x = \text{number of students "Meets+ Exceeds"}, \qquad n = \text{total number assessed}$$

This format supports a clear visual comparison across assessment elements and can also be presented across academic terms, allowing the Assessment Committee (AC) and faculty to easily observe trends and through higher resolution of this data, more readily identify potential problem areas to better determine effective continuous improvement actions.

4.3 Statistical sampling study

A statistical study was conducted to verify that our sampling methodology was appropriate overall, and to additionally assess the value of our reduced sample size pilot data from Spring 2024. Recall that Spring 2024 functioned as a pilot semester where a fixed sample size of approximately 20 students per section was used rather than statistically derived sample sizes based on actual class enrollment. To quantify the usefulness of the Spring 2024 data, assessment data for C3-2 from an Interdisciplinary Design Capstone taught in our Engineering Education Program with a large population of mechanical engineering students was analyzed. This was done because C3-2 SO element assessment tool data for whole population of students was accessible in Canvas. Recall that ABET C3-2 states, "[students must demonstrate] an ability to apply engineering design to produce solutions that meet specified needs with consideration of public, global, cultural, social, environmental, and economic factors." Criterion C3-2 was decomposed into its constituent elements, as detailed in Section 3.2. The corresponding breakdown is provided in Appendix A.1. This interdisciplinary design course had an enrollment of 81 students in academic year 2024-25, and all 81 students were assessed, which presented us with an opportunity to do a statistical analysis. It should be noted that the 81 students in this cohort are not exclusively mechanical engineering students; the dataset is drawn from a multi-program interdisciplinary course and is used here solely for the purpose of validating the statistical sampling methodology. These results do not represent official ME program accreditation data. Figure 7 shows the MES scores for samples corresponding to different confidence level (CL) values (with margin of error and population proportion held fixed at 10% and 50%, respectively as explained in section 4.2) for the six outcome elements of C3-2, the sample sizes here are computed using equation (1). In Figure 7, the confidence level is systematically reduced, with the leftmost bars representing the full population (CL = 100%, N = 81). The remaining groups show results at CL = 95%, 90%, and 70%, corresponding to smaller sample sizes. For these three groups, samples were drawn from various regions of the full population, while keeping the sample size constant. Each region began with a different random letter for the last name of students. Hence, the notations N_1^{90}, N_2^{90}, and N_3^{90} correspond to 3 random set of samples of 38 students each drawn from the full population based on 90% confidence level. It can be observed that the MES scores remain relatively stable, with only small variations, for CL ≥ 90%. In contrast, the CL = 70% (N_1^{70}, N_2^{70}, N_3^{70}) case, based on a sample size of approximately one-quarter of the full population, exhibits large variation in MES and therefore does not provide a reliable representation of student performance. The 20-sample pilot requirement for Spring 2024 was essentially equivalent to a CL = 70% sample size. Note the variation in the three sets of CL=70% data, with almost no overlap within respective error bar ranges. In contrast, the CL = 95% (N_1^{95}, N_2^{95}, N_3^{95}) results of Figure 7 indicate that meaningful and consistent attainment conclusions can be drawn using statistically derived samples. This means assessment of all students in a section is not required. This also confirms the sampling approach employed in the revised methodology provides robust representative data with Wilson interval error bars, computed using equation (2) and (3).

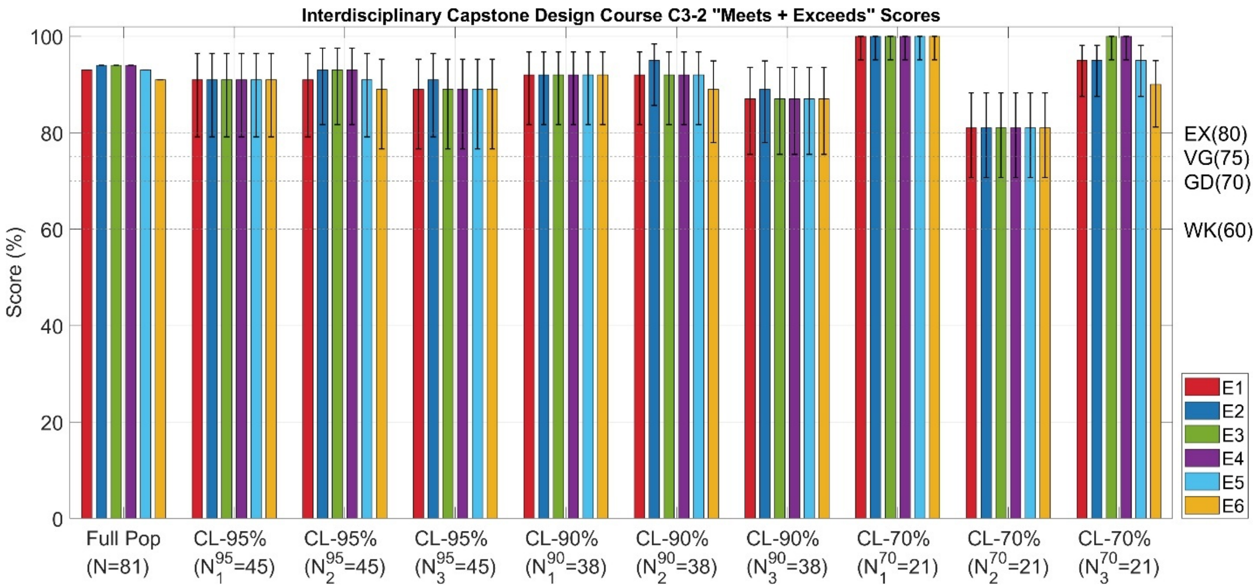

Figure 7. Statistical analysis showing the effect of varying confidence levels on data reliability at constant margin of error at 10% (E1-E6 represents the six decomposed C3-2 elements as shown in Appendix A.1) for the Fall 2024 Interdisciplinary Capstone Design Course.

4.4 Brief demonstration of higher resolution of new methodology

The statistical sampling study supported our designation of design parameters for the new methodology and gave us confidence in our new approach. It is also worth taking a closer look at Figure 1, which demonstrates the higher resolution of the new approach compared to a bulk SO evaluation (as was done in our 2019 approach) for C3-1.

In Figure 1, the error bars correspond to the 95% Wilson score confidence intervals [4], computed from the observed MES score and the actual sample size for each data point as explained in Section 4.2. The horizontal reference lines mark the levels of attainment described in Figure 4: Excellent (80), Very Good (75), Good (70), and Weak (60), where elements falling below the "Good" threshold trigger a continuous improvement discussion with the program's AC. The revised method immediately shows increased assessment resolution, thereby providing the opportunity for more detailed analysis of student performance

For example, Figure 1(a) reveals that element E4 attained a lower MES score than other elements, throughout all semesters. The element-level view also makes it possible to track which specific elements drive semester-over-semester changes, such as the overall decline observed from Spring 24 to Spring 25. In contrast, the presentation of C3-1 scores in the 2019 approach is limited to a single bar metric based on an assessment tool score, as shown in Figure 1(b), which could only give us information to investigate a broad overall trend. A single assessment tool score representing all elements may mask a lack of attainment in particular elements, and the single-metric approach from 2019 lacks the granularity to demonstrate attainment of all elements, providing lower-resolution data that may be less useful for determining continuous improvement actions, or may even result in the complete omission of underlying issues. This aggregation can obscure localized underperformance. For example, a single poorly performing element may be averaged with stronger elements, producing an overall score that appears acceptable. As a result, the actions implemented may either involve broad, unfocused interventions across the entire outcome or no action at all, thereby missing critical opportunities for targeted improvement.

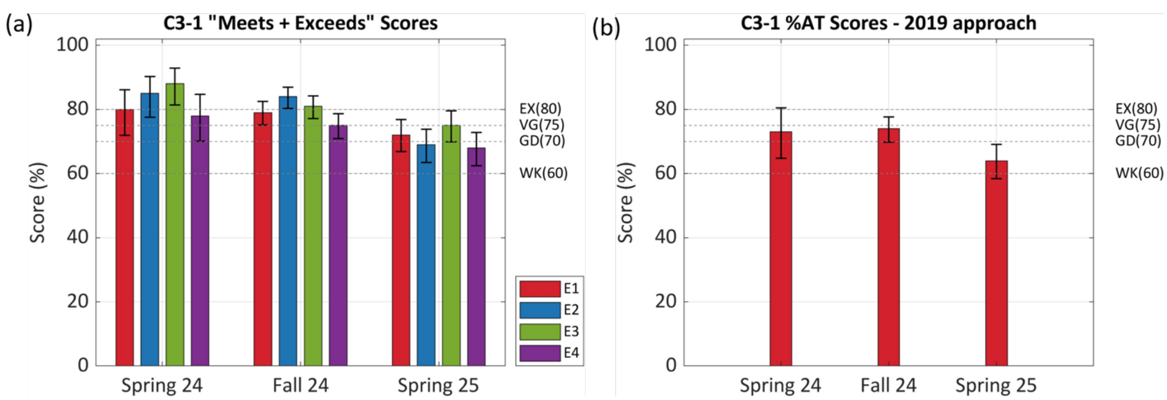

Figure 1. Comparison of ABET C3-1 program-level scores for the revised and former methodologies (E1-E4 represent the four decomposed C3-1 elements): (a) revised method, (b) former method[E1: Identify, formulate, and solve complex engineering problems, E2: Apply principles of engineering, E3: Apply principles of science, E4: Apply principles of mathematics][Attainment thresholds: EX=Excellent, VG=Very Good, GD= Good, WK=Weak]

4.5 Results and conclusion

Our methodology shifts away from a former program-level assessment approach that assigned a single assessment score to each SO to a revised approach that first decomposes an ABET SO into multiple independent and cognitively meaningful "elements" that are individually assessed and scored. The revised methodology provides a substantially greater level of granularity, or resolution, of student performance across all ABET SO elements as well as deeper visibility into program strengths and weaknesses.

The critical features of the revised methodology consist of separating each C3 SO into individual elements and using a consistent scoring metric across all tools. Each SO and associated elements is translated into an instructor tool template (Faculty Assessment Tool Template) and an individual scorecard for each section of a course (Faculty Assessment Rubric Scorecard Excel Spreadsheet).

The Faculty Assessment Tool Template is a standardized document that uses questions to guide faculty in the efficient identification and/or development of tools that assess *all elements* of a given SO. This work shows that completion of the tool template automatically generates a performance indicator for each SO element that reflects the pedagogical objectives and creative instincts of the instructor.

The Faculty Assessment Rubric Scorecard (Excel Spreadsheet) is standardized and is the instrument used by the instructor to record SO element assessment results for their assigned individual students using a standard metric. The consistency of the approach facilitates the quick aggregation of section-, course- and program-level assessment data.

Examples of program-level assessment results derived from the revised methodology are presented and discussed. The results serve to visually and quantitatively demonstrate the level of increased assessment resolution enabled by our approach by showing multiple scores for each SO to identify student attainment of each specific element of an SO. While our methodology was developed in the context of a large R1 mechanical engineering program, we expect it to be both applicable and beneficial to smaller engineering programs. Additionally, it lends itself to automation in an online system.

This work presents a systematic program-level assessment methodology developed to enhance and streamline the student outcome (SO) assessment and continuous improvement process required by ABET. The approach provides sufficiency in that assessment tools are articulated within the context of *each element* of a given SO, preventing a possible shortcoming if SO elements are not each clearly assessed. The approach provides consistency in that it is systematic and that it also uses general templates for identifying assessment tools for each SO that are applicable to any course, and it standardizes scoring of assessment tools across myriad tools that facilitates compilation of aggregate *program-level* assessment for program-level attainment measures for each SO needed for input into the Continuous Improvement process. The approach provides *efficiency* in the easy aggregation of program-level data, and in that it supports faculty in helping them understand ABET assessment needs through straightforward prompts that facilitates their efficient development of appropriate assessment tools that dovetail with their own respective curricular and pedagogical approaches.

5 Acknowledgment

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6 References

[1] ABET, “Accreditation Policy and Procedure Manual,” ABET, Baltimore, MD, USA, 2024–2025.

[2] EAC/ABET, “Criteria for Accrediting Engineering Programs,” ABET, Baltimore, MD, USA, 2025–2026.

[3] ABET, “Student Outcomes and Performance Indicators,” ABET, Baltimore, MD, USA, https://www.abet.org/wp-content/uploads/2017/02/Student-Outcomes-and-Performance-Indicators_revised.pdf.

[4] Virginia Tech Office of the Executive Vice President and Provost, Pathways Assessment Sampling FAQs, Blacksburg, VA, USA, 2018. [Online]. Available: https://www.pathways.prov.vt.edu/content/dam/pathways_prov_vt_edu/8pdf/Pathways%20Assessment%20Sampling%20FAQs%202018.pdf [Accessed: Feb. 27, 2026]

[5] NIST/SEMATECH e-Handbook of Statistical Methods, “7.2.4.1 Confidence intervals for proportions (Wilson method),” National Institute of Standards and Technology, Gaithersburg, MD, USA. Available: https://www.itl.nist.gov/div898/handbook/prc/section2/prc241.htm. [Accessed: Feb. 27, 2026]

A Appendix

A.1 Decomposition of ABET Criterion 3 SOs

<u>Criterion C3-1 states</u>:

“an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.”

Accordingly, C3-1 is decomposed into the following six assessment elements::

- Element 1: Demonstrate an ability to identify, formulate, and solve a complex engineering problem
- Element 2: Demonstrate an ability to apply principles of engineering
- Element 3: Demonstrate an ability to apply principles of science
- Element 4: Demonstrate an ability to apply principles of mathematics

<u>Criterion C3-2 states:</u>

“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.”

Accordingly, C3-2 is decomposed into the following six assessment elements:

- Element 1: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with public health, safety, and welfare factors.
- Element 2: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with global factors.
- Element 3: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with cultural factors.
- Element 4: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with social factors.
- Element 5: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with environmental factors.
- Element 6: Demonstrates an ability to apply engineering design to produce solutions that meet needs associated with economic factors.

<u>Criterion C3-3 states:</u>

“an ability to communicate effectively with a range of audiences.”

C3-3 does not require decomposition and is assessed as written by ABET.

- Element 1: Demonstrates an ability to communicate effectively with a range of audiences.

Criterion C3-4 states:

"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."

Accordingly, C3-4 is decomposed into the following six assessment elements:

- Element 1: Demonstrates an ability to identify ethical responsibilities.
- Element 2: Demonstrates an ability to identify ethical responsibilities.
- Element 3: Demonstrates an ability to understand impact of engineering solutions in global contexts.
- Element 4: Demonstrates an ability to understand impact of engineering solutions in economic contexts.
- Element 5: Demonstrates an ability to understand impact of engineering solutions in environmental contexts.
- Element 6: Demonstrates an ability to understand impact of engineering solutions in societal contexts.

Criterion C3-5 states:

"an ability to function effectively on a team whose members together provide leadership, create a collaborative environment, establish goals, plan tasks, and meet objectives."

Accordingly, C3-5 is decomposed into the following five assessment elements:

- Element 1: Demonstrates an ability to provide leadership to the team.
- Element 2: Demonstrates an ability towards creating a collaborative and inclusive environment.
- Element 3: Demonstrates an ability to establish goals.
- Element 4: Demonstrates an ability to plan tasks.
- Element 5: Demonstrates an ability to meet objectives.

Criterion C3-6 states:

"an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions."

Accordingly, C3-6 is decomposed into the following four assessment elements:

- Element 1: Demonstrates an ability to develop appropriate experimentation.
- Element 2: Demonstrates an ability to conduct appropriate experimentation.
- Element 3: Demonstrates an ability to analyze and interpret data.
- Element 4: Demonstrates an ability to use engineering judgment to draw conclusions.

<u>Criterion C3-7 states:</u>

"an ability to acquire and apply new knowledge as needed, using appropriate learning strategies."

Accordingly, C3-7 is decomposed into the following two assessment elements:

- Element 1: Demonstrates an ability to acquire and apply new knowledge as needed.
- Element 2: Demonstrates an ability to use appropriate learning strategies for acquiring and applying new knowledge.

A.2 Sample Faculty Assessment Tool Template

VTME ABET Assessment Tool Instructions for Assessing ABET Student Outcome C3-1

Instructor Name: *Dr. Jane Doe*
Course Name and Number: *ME4XXX: Dynamic Systems, Vibrations.*
Section Number: *XXXXXXX*
Semester: **Spring 2026**

ABET Student Outcome C3-1: [Students must demonstrate] an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.

Faculty Instructions:

1. Choose **one** test problem, final exam problem, quiz problem, etc., that is a good assessment tool for this Student Outcome C3-1

2. Please fill out the information below for your chosen assessment tool, and attach a copy of the assessment tool and solution.

   a. Name of Assessment Tool (for example, *"final exam problem 3"*): *Test #2 Problem 2*

   b. Describe briefly why your assessment tool is considered a complex engineering problem.
   The problem requires students to model a real-world system, a washing machine with a specific unbalance load, and determine the forced response (vibration level due to unbalance). They then must specify the maximum allowable unbalanced mass (as a weight in correct units) for a specified standard vibration limit. It requires that students understand how to make the correct assumptions to determine an appropriate physics-based model of a complex system, determine and solve an associated mathematical model, and understand engineering specifications and units.

   c. In your assessment tool, how does a student demonstrate that they have identified, formulated, and solved the problem correctly?
   Students must show a correct physics-based model of the washing machine as a Single Degree of Freedom (SDOF) system, generate the correct equation of motion with correct forcing function due to unbalance, and use the equation to determine a maximum allowable unbalance for a given vibration limit.

   d. In your assessment tool, how does a student demonstrate that they have an ability to apply principles of engineering to solve this problem?
   Students must demonstrate that they can simplify a complex real-world system into a SDOF model by making appropriate assumptions, translate the SDOF model into a mathematical model and solve it to determine the dynamic

response (vibration level) of the system. They then must demonstrate that they can use the information to specify a maximum allowable unbalance load for the washing machine given a maximum vibration limit.

e. In your assessment tool, how does a student demonstrate that they have an ability to apply principles of science to solve this problem?

Students demonstrate this through their application of Newton's Laws from physics to determine a SDOF free-body diagram of the system and the associated equation of motion.

f. In your assessment tool, how does a student demonstrate that they have an ability to apply principles of math to solve this problem? Note: ABET defines math as "calculus, differential equations, probability, statistics, linear algebra, and discrete mathematics." (you could use one type or a mix, it's your choice).

Students demonstrate this by solving their equation of motion, which is a 2nd order differential equation with a sinusoidal forcing function, in order to determine the dynamic response/vibration level of the washing machine.

3. Please provide:
    a. Filled-in ABET Assessment Tool template (this document).
    b. A filled-in ABET assessment rubric spreadsheet. You will receive a pre-populated rubric spreadsheet to assess a subset of students in your class. The list of students to assess will start with students whose last name begins with the **letter C** and proceed alphabetically until the sample size (as determined statistically by the department) is reached. You are free to populate this list yourself; otherwise, my GTA can do this for you
    c. A copy of the tool you have chosen and its solution. (you may reach out to my GTA to make digital copies if needed)
    d. Two examples of graded student work for your tool representing "high," "medium," and "low" performance (six examples total). This can also be retrieved by our GTA if granted Canvas access (and assuming the documents are uploaded there).

Comments:

Note that I have separated my test problem into individual steps with associated point values to aid in filling out the ABET Assessment Rubric Scorecard in Excel. For example, determining the free body diagram and associated equation of motion is one step, solving the 2nd order ODE for a vibration level is another step, etc.