A Faculty-Guided Continuous-Improvement Regimen With ABET Student-Outcome Scaffolding

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Every ABET-accredited program must satisfy Criterion 4, which requires that programs carry out regular, documented procedures for assessing and promoting student attainment in its designated ABET Student Outcomes (SOs). These procedures are collectively denoted "Continuous Improvement" (CI).

This paper describes a practical CI regimen which utilizes faculty SO oversight committees, one for each ABET-designated SO. Each three-to-four member SO committee has broad oversight responsibility for student attainment in its respective SO, including assessments, evaluations, and curricular recommendations. This CI regimen has both engaged the faculty and enhanced our Program's alignment with its designated ABET Student Outcomes.

Keywords: program assessment, ABET Criterion 4, continuous improvement

INTRODUCTION

This article enlarges on a conference paper presented during the mechanical-engineering division Program Assessment session at the 127th ASEE Annual Meeting. The conference paper (Peridier, 2020) introduces a practical, faculty-managed "continuous improvement" regimen that is designed to foster (and demonstrate) compliance with General Criterion 4 of the ABET Accreditation Criteria (ABET/EAC, 2019).

This "practical, faculty-managed continuous-improvement regimen" may well be of interest to any of the over 4000 academic programs accredited by the Accreditation Board for Engineering and Technology (ABET). This is because every academic program accredited by ABET must demonstrate compliance with General Criterion 4, "Continuous Improvement." It emerges that ABET General Criterion 3 informs Criterion 4, so let us first consider Criterion 3.

Criterion 3 ("Student Outcomes") lists a mandatory "minimum set" of student competencies that an ABET-accredited program must foster in its students. ABET has four subsidiary commissions; each produces an Accreditation Criteria with its commission-specific mandatory minimum set of student outcomes enumerated in Criterion 3. For example, one of these four commissions is the Engineering Accreditation Commission, and seven mandatory student outcomes are listed in its accreditation criteria (ABET/EAC, 2019; here on called the <u>Criteria</u>). The academic engineering community's shorthand for these seven student outcomes is SO 1-7.

Criterion 4 ("Continuous Improvement") requires academic programs to use documented processes for assessing and furthering student attainment in the Student Outcomes listed in Criterion 3. The text of Criterion 4 for all four commissions, and thus for *every* program accredited by ABET, is:

> "The program must regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for continuous improvement of the program. Other available information may also be used to assist in the continuous improvement of the program."

Thus, all ABET-accredited programs, irrespective of discipline, must demonstrate compliance with Criterion 4 exactly as stated above. Criterion 4 in effect requires regular and systematic program-level assessment, with a specific focus on the mandated Student Outcomes. Criterion 4 also stipulates that the evaluations be systematically utilized and documented. The CI regimen described in this paper facilitates compliance with these requirements.

Since CI is specifically concerned with Student Outcomes, the core operational framework of the CI regimen described in this paper is organized in a parallel manner to the Student Outcomes. For example, our (mechanical-engineering program) CI regimen has seven (three-to-four member) standing faculty oversight committees, one for each SO 1-7. Each committee has broad authority for carrying out assessment, examining the scaffolding of the pedagogy for their designated SO within the curriculum, and making specific Program recommendations to the Chair.

Although this basic framework is simple in concept (i.e. an oversight committee for each SO), both coordination and planning are needed to make it effective. So the goal of this paper is to provide sufficient specifics to illustrate how this all works in practice. Specifically, the five major components of our CI regimen: (i) the SO oversight committees, (ii) the performance indicators, (iii) the assessment mechanics, (iv) the documentation, and (v) the archival practices, are each addressed in turn. But before considering these five topics, let's begin with the core concern of CI, namely student outcomes and their attainment.

STUDENT OUTCOMES AS A FRAMEWORK TO IMPROVE THE PROGRAM

Below are listed the seven ABET/EAC Student Outcomes, SO 1-7, for programs accredited by the Engineering Accreditation Commission. The SO 1-7 are presented here in part to facilitate the discussion which follows with its many specific examples. However, should your program have a different number (or a different set) of student outcomes, the basic tactics and procedures are readily adapted.

The ABET/EAC SO 1-7 are:

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 judgements, which must consider the impact of engineering solutions in global, economic, environmental, and social 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 judgement to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The above seven student outcomes were developed by consortium of professional-engineering societies specifically for the function of accrediting engineering programs. So, it is noteworthy ---and perhaps a little unexpected--- that only three of the seven student outcomes are technical, or specific to STEM. The other four student outcomes describe "soft skills" that engineering students need to be effective engineering professionals. Consequently, an academic-engineering Program's commitment to systematically foster student attainment in SO 1-7 is important, and not just because it meets an ABET accreditation requirement.

CI is a worthy process because its objective is to foster skills attainment that will empower students in their subsequent professional careers.

CREATE FACULTY "SO OVERSIGHT COMMITTEES," ONE FOR EACH SO

The foundational component of our Program's CI regimen is its seven standing SO 1-7 oversight committees (SO-1, SO-2, ... , SO-7). Each committee consists of three or four faculty members, and the duties of each SO 1-7 committee include:

- identifying specific assessments to be carried out for the SO in its purview,
- evaluating the completed assessments for the SO in its purview,
- discussing the committee's collective experiences and challenges for delivering effective student experiences in this SO, and
- making curricular/program recommendations to the Chair and/or Program as needed.

The Assessment Coordinator (who facilitates the CI procedures for the Program) recruits individuals to serve on the SO 1-7 committees, and faculty with relevant academic responsibility are approached first. For example, the capstone-project faculty are recruited for the SO-2 ("engineering design") committee, the technical-writing course coordinator is recruited for the SO-3 ("communication") committee, and the curricular-lab faculty are recruited for the SO-6 ("experimentation") committee. Beyond this, faculty may volunteer for a specific SO committee based on personal interest or pedagogical expertise.

Finally, for the "technical" student outcomes (i.e. SO-1 "engineering problem solving," SO-2 "engineering design," and SO-6 "experimentation") the Assessment Coordinator recruits both thermal-systems and mechanical-systems faculty for each of the corresponding student-outcome committees. This is because the accreditation Criteria specific to mechanical engineering identifies thermal and mechanical systems as the twin core topic areas for BS ME students.

The Assessment Coordinator convenes the seven SO-specific committees individually, and each SO committee meets at least once during the academic year (normally in the fall term) but no more frequently than once a semester. Assessment materials and discussion items are distributed in advance of the meeting by the Assessment Coordinator, with the goal of keeping the meeting both focused and efficient.

During a SO-committee meeting, the faculty review and discuss the assessments that were carried out in the prior year, focusing on out-of-norm scores; other available data (e.g. student surveys) may also be considered. Then the committee selects at least one specific assessment for each of the three or four "performance indicators" associated with this SO, to be carried out in the current academic year. (Performance indicators and assessment mechanics are considered below.)

Having settled on the assessment instruments for the current academic year, the discussion naturally segues to the committee members' experiences for pedagogy in this SO, to the programmatic scaffolding of the SO in the curriculum, and to the changes and adjustments that might be made. Our three-to-four-member SO oversight committees seem right-sized for facilitating cross-cutting department conversations about curricular content, program scaffolding, and how better to foster SO-relevant student experiences.

After each SO-committee meeting, the Assessment Coordinator provides a summary of the committee's findings and recommendations in a written memo to the Department Chair. Because the recommendations are specific, data-driven, and due to faculty deliberation, the memo both facilitates and validates subsequent actions by the Chair. Thus, the SO-committee deliberations create momentum for curricular refinements that ultimately improve our Program and the SO attainment of our students.

DEVELOP PERFORMANCE INDICATORS

Section 2 above ("create faculty SO oversight committees ...") described both the recruitment and the routine function of each SO committee, once the CI regimen is up and running. However, when the Program first implements this CI regimen by recruiting its inaugural SO committees, each committee's top order of business should be to devise two-to-four "performance indicators" for the SO in their purview.

The performance indicators for a given SO define subsidiary competencies which are: (i) consistent with the text of the student outcome, (ii) specific to the Program, and (iii) expressed as student work in the curriculum. Thus, performance indicators provide the SO committee with targeted, specific, capabilities and/or experiences for which to assess student attainment of the SO in the Program. Our Program's current set of performance indicators, by way of illustration, is given in Appendix A. Note that, in our Program's enumeration scheme, SO-3.b is the second performance indicator for SO 3.

Performance indicators are useful, and five observations based on our Program's experience are offered here. The first observation is that the text of a given performance indicator should hew *closely* to the specific ABET language for the SO. The goal for a set of performance indicators is that, collectively, they span all competencies suggested by either the SO or any relevant definitions provided in the Criteria.

It happens that all four ABET accreditation commissions recently modified their enumerated student outcomes, effective in the 2019-2020 academic year. This means, for example, that academic-engineering programs must now migrate their assessment practices from the former SO a-k (pre 2019) to the current SO 1-7, and the second observation applies to programs in the midst of this transition. ABET revised the SOs and definitions in the new Criteria with intent, so simply mapping one's former SO a-k performance indicators to the new SO 1-7 may not yield the best result. Indeed, it is a valuable exercise for the SO committee to "start fresh" and devise performance indicators that specifically integrate the *new* language of the Criteria. This is because the activity of devising new performance indicators compels the committee to collectively reflect on the implications of the SO and its attendant implied competencies.

The third observation is that performance indicators enable the Program to particularize SO attainment in a fashion consistent with the Program's mission or concerns. For example, when our Program's SO-4 ("professional ethics") committee initially discussed the text of the following candidate performance indicator:

(SO-4.a) "adheres to academic honesty codes in studies of engineering and other subjects."

Some of the members felt that the proposed performance indicator did not align well with the overall "professional practice" tone of SO 4. However, the above candidate performance indicator was eventually adopted, and for two reasons. First, it is arguable that academic-honesty codes are a *de facto* professional-ethics code for students. Second, surveys conducted by our Program consistently show that students are very concerned about cheating. So as a consequence of our Program's adoption, assessment, and evaluation of performance-indicator SO-4.a, (i) academic honesty is now a topic in the required curriculum, and (ii) a regular assessment of student attitudes concerning academic misconduct is carried out every year.

The fourth observation is that performance indicators are simply devices to help the Program monitor and foster student attainment in a given SO. Programs evolve, and so does a SO committee's view for how best to integrate the SO within the curriculum. For both reasons, a SO committee may wish to modify a performance indicator, and this is a good thing because it means the committee appreciates that performance indicators are utilitarian constructs to be refined as needed. Indeed, our Program's SO-2 ("engineering design") committee refined the SO-2 performance indicators several times, to better integrate the text of SO-2 with the Criteria's expanded preamble definition of engineering design. It happens that the SO-2 committee converged on a set of performance indicators that incorporates the language and concepts of the "10 Steps of Design Thinking" as posted on the MIT Professional Studies website:
https://professional.mit.edu/news/news-listing/10-steps-design-thinking

Fifth, to "quantify" student attainment in a given performance indicator or student outcome, a scoring device such as a rubric is needed, and either generic or assignment-specific rubrics are possibilities. Generic rubrics are useful when a large variety of student assignments are used to assess a given student outcome (e.g. assessing "quantitative literacy" using student work from a University-wide spectrum of courses). On the other hand, if a single common assignment is used to assess a performance indicator, then an assignment-specific rubric is more readily interpreted and thus more useful for scoring.

Under our Program's *former* CI scheme, faculty were asked to assess their own classes' assignments using a single, generic, committee-devised, College-wide set of performance-indicator rubrics. However, these generic College-wide rubrics proved unsatisfying because they were voluminous (pages upon pages of tiny print), confusing to the faculty, and too nonspecific to be confidently applied in practice. Instead, as will be seen, in the *current* CI regimen under discussion, the SO committee identifies a specific item of student work to be assessed, making assignment-specific rubrics the most natural and targeted scoring scheme for the faculty assessors.

So due to the selective, targeted assessment instruments identified by the SO oversight committees, this CI regimen employs assessment-specific rubrics. Assessment mechanics are described next.

ASSESSMENT MECHANICS

The goal of assessment is to gauge student attainment, upon completion of the Program, in each Student Outcome. To gauge this attainment, each SO committee is charged with selecting at least one specific "summative" assessment instrument, for each of its performance indicators, in every academic year. A "summative" assessment instrument is one that reflects the mature, accumulated experienced of a student, for that performance indicator, over the course of the Program.

The SO committee's objective of selecting at least one summative assessment instrument, for a given performance indicator in a given academic year, will have one of three possible outcomes:

1. A summative "direct assessment" instrument is selected by the SO committee. A direct assessment is a piece of student work (an assignment, a quiz question, a presentation) that can be evaluated by a third party. Direct assessments are normally the least subjective of the assessment methods and thus preferred.
2. Alternatively, an "indirect assessment" instrument (a student survey) may be selected by the SO committee, because some performance indicators present practical difficulties for third-party evaluation. In this situation the SO committee may choose to survey the students concerning their individual perception of their competency.
3. A third possibility is that the SO committee is unable to identify a suitable assessment instrument in the required curriculum for a given performance indicator. This situation is a key mechanism in our Program's CI regimen for identifying aspects of the curriculum that need remediation, leading ultimately to the improvement of the Program.

Specific examples for each of the above three assessment-selection outcomes are now considered, beginning with direct assessment.

Direct-Assessment Mechanics

Our Program's direct-assessment mechanics will be described here by way of example. Suppose the SO-1 committee decides that this year's assessment instrument for SO-1.b will be a fluid-mechanics test question on the application of the Bernoulli equation. With this decision, the following direct-assessment steps take place.

1. The Assessment Coordinator relates this SO-1 committee direct-assessment request to the fluid-mechanics instructor, who in turn confirms that a Bernoulli-equation quiz question will be given, and when the quiz will be given.
2. After the quiz is collected, but *before* the quiz is graded, the Assessment Coordinator selects twenty quizzes (of confirmed mechanical-engineering-student work, hewing to program-disaggregation requirements) and, from these twenty samples, makes two sets of xeroxed copies of the (Bernoulli quiz-question) student-composed solutions. The original quizzes are then returned to the instructor.
3. The Assessment Coordinator then recruits both: (i) the course instructor, and (ii) a second, experienced fluid-mechanics instructor, to assess the Bernoulli quiz question. Each of these two assessors is provided with one of the two sets of xeroxed student work
4. Each assessor, separately and independently, score their copy of the twenty samples on 1-5 Likert scale using the following "rubric" gradations of scale:

[5] outstanding. A professional-quality response; answer *exceeds expectations*; the student anticipates atypical situations for the problem, and so on.
[4] target. This is the answer reflects the instructor's *target student competency* for the problem.
[3] baseline. This answer, while not at target competency, demonstrates that the student has an *acceptable baseline competency* in the topic.
[2] subpar. This answer falls short of minimal baseline competency, but nevertheless suggests that the student has some right ideas.
[1] unsatisfactory. The student has "no clue."

5. Each faculty assessor, independently of the other, returns their scored copies of the quiz questions to the Assessment Coordinator, who computes the average and the standard deviation for each faculty assessor's sample.
6. The Assessment Coordinator reports the results to both assessors and archives the quiz question and samples of student work in the categories **[1]-[5]** in both a physical repository and an electronic data base.
7. The assessment scores, standard deviations, and any additional observations provided by the two assessors are discussed at the next SO-1 committee meeting.

Our Program has been using the above direct-assessment procedure for nearly three years and the following has been our experience. First, that *two* faculty *separately* assess the same set of student work has conferred a gravitas to "assessment" that did not exist in our Program's former CI process. Conscious that a second experienced individual is also scoring the same set of student work, faculty assessors are thoughtful in their assessment and often annotate the samples with helpful observations.

Our Program's experience to date indicates that the above-described "rubric" suffices without further elaboration if (i) the assessment instrument is relatively specific (like a quiz question), and (ii) the two faculty assessors are experienced instructors of the discipline. This is because (for example) two experienced fluid-mechanics instructors, given a Bernoulli-equation problem, will likely have comparable expectations in the categories of "outstanding," "target," "baseline," and so on, Indeed, in our Program's experience, the few situations wherein the two assessors' respective average scores differed significantly occurred when one faculty was comparatively inexperienced.

However, for assessment instruments of more complexity than a single test question (e.g. a written report or a design project) a more detailed rubric may need to be devised to enable the two faculty assessors to apply a consistent weighting for the subsidiary components of the student work. In this case the Assessment Coordinator and the two faculty assessors meet and jointly devise a rubric which is (i) specific to this assignment, and (ii) consistent with the competency gradations of the above-described Likert scale. The two faculty assessors use this mutually-devised assessment-specific rubric in their respective independent evaluations. Both the assignment prompt and this assignment-specific rubric are archived, along with the samples of student work, by the Assessment Coordinator at the conclusion of the assessment.

The reason that the Assessment Coordinator reports both the average score *and* the standard deviation in any subsequent communiques is because, even with our solid sample size of twenty, the standard deviation of the assessment scores has proved to be large (e.g. 3.7 ±1.2). Because there are only two faculty assessors (who moreover are experienced in the discipline), the deviation of the scores must be ascribed to underlying variation in student competency for the performance indicator in question. So owing to the genuine and substantial underlying variation in student attainment, our Program consistently reports both the average score and its standard deviation.

Finally, how does the SO committee use these direct-assessment scores? Given the Likert-scale scoring strategy described above, if an overall average score is between 3.0 and 4.0 for a performance-indicator assessment, the committee will conclude that no remediation need be taken. Scores consistently above 4.0 from year to year are not common in our Program assessments, except for certain specific assessments (e.g. the scores for "oral presentation" of the capstone senior-design projects).

However, should an averaged direct-assessment score of less than 3.0 occur in two successive years for a given performance indicator, the committee will discuss the situation and, based on their collective experience, recommend a curricular adjustment. For example, the recurring faculty refrain that "our students cannot write!" was confirmed in successive direct assessments of technical writing. In response, the SO-3 committee examined the Program curriculum concluded that, except for a single dedicated technical-communication class, there was a dearth of individually written and/or individually graded technical-writing assignments. Consequently, the SO-3 committee recommended: (i) that the Program add writing-intensive components to another required course in the curriculum, and (ii) that curricular-lab reports --formerly written by teams of students-- be now individually written and graded. These enhancements to our Program are in the process of being implemented, and the SO-3 committee will review the data in the next few years to discern if these curricular remediations have improved our students' writing competency.

Indirect-Assessment Mechanics

In the inaugural year of our Program's CI regimen, the Assessment Coordinator conducted an "indirect assessment" (i.e. a student survey) "in parallel" with each direct assessment carried out as a second, corroborative measurement. However, this practice was discontinued after the first year for two reasons. First, students reliably rated their competency higher than did the faculty (by more than a Likert scale point), so the indirect assessment turned out to be a quite predictable exercise that failed to add new information. Second, today's students are said to be over-surveyed (a common explanation for the low response rate when online surveys are deployed). Consequently, SO committees now elect to carry out an "indirect assessment" (i.e. a student survey) of a given performance indicator only if direct assessment proves impractical.

To illustrate our Program's indirect assessment mechanics, again by way of an example, consider SO 7, which addresses that students, in their subsequent professional careers, will need to both teach themselves, and apply, new knowledge. SO 7, further, requires that the Program incorporate experiences wherein students devise a personal and "appropriate learning strategy."

This author views SO 7 as a particularly important student outcome for engineering programs to foster. Why? An unfortunate side effect of our hierarchically-scaffolded engineering curricula, with their very specific learning paths, is that engineering students have limited agency for devising personal learning strategies. Even within a given engineering class, the topics are likely to be both (i) closely curated, and (ii) systematically sequenced, to optimize student learning. So how and/or where does an engineering student gain experience in devising their own "appropriate learning strategy" as described in SO 7?

The SO-7 committee wrestled with this conundrum and concluded that, in our Program, the most likely candidate classes where students may need devise appropriate learning strategies to acquire new (i.e. "extracurricular") knowledge are their three upper-level technical elective courses, because these classes are often cross-disciplinary or of a professional focus. However, given the broad diversity of our Program's technical-elective course topics, direct assessment of SO-7 performance indicators in the technical-elective courses was ruled out as impractical.

Instead, the SO-7 committee decided to issue a survey to every student enrolled in a technical-elective class, and the goal of this assessment was quite modest. The SO-7 committee was simply trying to ascertain: (i) what fraction of students in each technical elective course found that they needed to learn new (extracurricular) knowledge to do an assignment, (ii) what learning resources did students use (SO-7.a), and (iii) how successful were students at applying their knowledge (SO-7.b)?

So again, by way of example, the steps for carrying out this indirect assessment were:

1. The SO-7 committee and the Assessment Coordinator developed a survey questionnaire. (This survey is shown in Appendix B. Note that indirect assessments should be carried out as anonymous surveys, and thus the survey questions concerning the student's academic program are used for data disaggregation purposes.)
2. The Assessment Coordinator conferred with each technical-elective-course instructor concerning their preference for conducting the survey in their respective classes.
    a. If the instructor agreed to provide in-class time for the survey (and it is a short survey) paper copies were provided for the instructors to distribute/collect.

b. If the instructors preferred that their students complete the questionnaire outside of class, it was implemented as an anonymous survey in the course's online learning management system (our institution uses CANVAS).
3. The surveys were then tabulated, archived, and the aggregate results communicated to both the instructors and the SO-7 committee.

Unsurprisingly, in the semesters following the initial SO-7 survey, the technical-elective faculty began to issue assignments wherein students needed to learn and apply extra-curricular knowledge. This suggests that the process of using a student survey to gauge SO-7 attainment may have motivated faculty to create these sorts of assignments going forward.

Beyond committee-developed surveys, our Program's SO 1-7 committees also utilize surveys developed by third parties. For example, our SO-5 ("teamwork") committee utilizes third-party online peer-assessment tools to survey senior-design teams concerning their colleagues' teamwork skills. As another example, the SO-4 ("professional ethics") committee devised a variant of the PACES survey (Carpenter *et al*, 2010) to gauge engineering student attitudes towards cheating; this survey is conducted in the junior-year course "Engineering Seminar."

When No Suitable Assessment Instrument for a Performance Indicator Can Be Identified

When a SO oversight committee cannot identify a suitable assessment instrument for a given performance indicator within the required Program curriculum, the likely culprit is that no student experiences (i.e. assignments) are taking place for that competency. The SO committee may flag this situation as evidence of curricular weakness and will then recommend one or more specific programmatic remedies. CI takes place when the Program implements SO-committee recommendations that ultimately yield assessment-quality student work for the performance indicator in question. Two recent examples from our Program follow.

In the 2018/2019 academic year, the SO-4 ("professional ethics") committee concluded that there were no graded assignments in the required curriculum wherein students evaluate the socio-economic-environmental impact of an engineered design (SO-4.c). It happened, in this same year (and as described above), that the SO-3 ("communication") committee concluded that students needed more individually-written and -graded technical writing experiences (SO-3.a) in the required curriculum. So, in a coordinated response to both issues, a required course in our Program (Engineering Economics) is being reworked so that (i) it is writing-intensive, and (ii) it includes a student-written analysis for the economic impact of both global warming and health-care costs on an engineering-design proposal.

As a second example, the language of SO 6 ("experimentation") suggests that students should have experience in developing experiments (SO-6.c). The SO-6 committee realized that the student experience of developing experimentation was not integral to any of our Program's required curricular labs. The consequent Program response has resulted in a revised pedagogy for the senior-year curricular labs, specifically to incorporate at least one major project in which an experiment is to be devised. This curricular adjustment is a consequential improvement in the curriculum vis-a-viz SO-6 student attainment.

CARRY OUT CONTINUOUS-IMPROVEMENT DOCUMENTATION

As required by Criterion 4, our Program documents (i) assessments (data and evaluations), and (ii) CI discussions that arise in academic meetings. To document meeting deliberations, our Program uses a template memoranda device ("CI Memo") to record the discussions in formatted, consistent manner.

It is obvious that memoranda of the deliberations for every SO 1-7 committee meeting need be kept and archived for CI documentation. This is because all discussions in every SO 1-7 committee meeting bear directly on SO attainment in the Program.

Note that a reliance on regular meeting minutes to capture instances of CI-specific discussion in other types of academic meetings (e.g. department or college) can be problematic. This is because the core agenda topics of conventional academic meetings are not necessarily specific to SO attainment. Indeed, in regular academic meetings there is often just a passing remark or suggestion, relevant to CI, that one would like to record for later reference. In our former CI regimen, the Program attempted to document CI-relevant remarks simply by highlighting the original meeting minutes, but this proved an unsatisfying and haphazard strategy.

Our Program's response to this difficulty is that the Assessment Coordinator now records a separate CI Memo during every type of academic meeting, noting solely those components of the discussion deemed specific to CI, and annotating the CI Memo with implications for SO attainment and follow-up tasks. So, in addition to the documentation of assessments, our Program's Continuous Improvement documentation includes the following:

- CI Memos for every SO 1-7 committee meeting
- CI Memos for Department meetings
- CI Memos for departmental industrial advisory committee meetings
- CI Memos for College and/or Department Retreats
- CI Memos for Program annual review

DEVELOP A COMPREHENSIVE CI/ASSESSMENT ARCHIVE

This section describes our Program's assessment/CI digital archive. The archive was initially implemented solely as a compliance device for Criterion 4, but it has since proved so useful that it is now difficult to imagine managing the Program without it! CI has many moving parts and having a comprehensive and organized scheme in place, from the get-go, to manage the disparate data entities has proved critical for success.

All primary, secondary, and supporting data/documentation relevant to our Program's continuous improvement is electronically archived on a dedicated filesystem which resides on the Assessment Coordinator's office computer. This archival filesystem, in turn, is backed up on two, duplicate, offline, terabyte drives when any change is made to the original computer-resident data.

This assessment/continuous-improvement filesystem has three subdivisions: (1) an ABET/SSR Repository, (2) the Continuous-Improvement Documentation, and (3) our Department Supporting Data. The organization of each subdivision is now briefly described.

The ABET/SSR Repository

This ABET/SSR repository is partitioned in two subsidiary components: "ABET" and "SSR." The "ABET" portion contains a folder for all correspondence to/from ABET, and another folder for ABET-published resources.

The "SSR" (for "self-study report") component was initially envisaged as a repository for the Program's most current data in each of the SSR Criteria, and thus it contains a directory for each of the SSR Criteria 1-8. However, as a practical matter, only Criterion 2 ("PEO") through Criterion 6 ("Faculty") are actively maintained by the Assessment Coordinator, and each directory for these five criteria includes documentation in sufficient detail that a rationale for the Program evolution (in that Criterion) can be reconstructed.

Continuous-Improvement Documentation

This "folder" has two subsidiary folders: "Assessments" and "CI Documentation." The "Assessments" folder has the assessment data, with a sub-folder for each SO 1-7. Within each SO-x folder are separate folders for each assessed course, and within each assessed-course folder are the academic year of the assessment, and within the year are the samples of student work, the tabulated assessment scores, the assessment rubrics, and so on.

The second subsystem for "CI Documentation" has two folders, one for the SO-committee deliberations, and the second for the CI-memos composed during for the other types of academic meetings. Unsurprisingly, the SO-committee folder is organized by SO committee, then academic year. The CI-memoranda folder is organized by type of meeting (IAC, Dept, Retreat), then academic year.

Department and Institutional Supporting Data

In this subsystem resides the miscellany of "other data" used in support of any continuous-improvement activity. There is a repository for institutional student records (principally class lists that are used to disaggregate assessment data). There is a repository for NCEES/FE results (and the software used to convert this to Likert-scale assessment data). There is a repository for course-section student-feedback data, a repository for all original academic meeting minutes (by meeting type, academic year), and a repository for Temple University's institution-specific internal assessment correspondence.

CONCLUSION: MAKING IT ALL WORK

Thus far, our Program's CI regimen and assessment protocols can be credited with several concrete curricular initiatives that will likely enhance our students' attainment in SO 1-7. But to be successfully deployed and effective, three components are required to make it all work.

The preeminent and most critical component of our Program's CI regimen are those seven faculty SO 1-7 committees, with each committee having dedicated oversight for student attainment in its specific SO. The programmatic benefit of having a diversity of faculty deliberate on SO-related topics cannot be overstated. Indeed, most of the "really good ideas" for the curricular improvements launched by our Program arose in brainstorming sessions during our Program's SO 1-7 committee meetings.

The reader might reasonably be skeptical that faculty, uncoerced, would willingly serve on "yet another committee." However, our faculty's support of our SO committees has been unqualified, and they likely have three incentives for participation. Faculty who serve on SO committees have the satisfaction of both (i) exchanging views on fundamental pedagogical issues with each other, and (ii) the possibility of effecting real change within the Program. The third (iii) incentive for participation is that the meetings are focused, and occur no more than twice a year. Consequently, for our Program, SO-committee recruitment has not proved difficult. Indeed, some faculty serve on multiple SO committees, and in our Program both tenure/tenure-track and non-tenure (instructional) faculty are well represented.

A second critical component is the Assessment Coordinator. This individual plans and convenes every SO-committee meeting, coordinates and tabulates all the assessments, and composes all the CI memorandum for both the varied faculty meetings and for the SO-committee deliberations. This individual, in concert with the Department Chair, coordinates and facilitates the Program enhancements recommended by SO committees. This individual also keeps the assessment archive up-to-date and stays abreast of ABET developments. Thus, the appointed individual should be organized, familiar with ABET regulations, and knowledgeable concerning the Program curriculum. Given the ongoing, persistent, and somewhat time-consuming activities entailed, the equivalent of a course release per semester is recommended for Assessment-Coordinator duties.

The third critical component is having a cognizant administrator (for our Program, it is the Department Chair) who is willing to allocate the time and resources needed to implement recommendations made by the SO committees. Our Program has been fortunate to have a Department Chair who responsively entertains the recommendations of the SO 1-7 committees, and who proactively facilitates the continuous improvement of both our curriculum and for student attainment of the SO 1-7.

REFERENCES

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APPENDIX A
EXAMPLE OF PERFORMANCE INDICATORS

(The SO 1-7-committees developed this set of performance indicators for the BS ME Program, Temple University.)

SO-1 "An ability to identify, formulate and solve complex problems by applying principles of engineering, science and mathematics."

(SO-1.a) Identifies, formulates, and solves well-defined (text-book) engineering problems.

(SO-1.b) Identifies, formulates, and solves engineering situations complicated by a lack of (or inconsistent) technical requirements, using a reasoned, justified solution strategy.

(SO-1.c) Uses appropriate numerical and/or computational analysis to study or solve engineering problems.

(SO-1.d) Identifies, formulates, and solves complex engineering problems that span multiple disciplines.

SO-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." (see note)

(SO-2.a) Identifies the need for the engineered solution; assembles relevant information for the development of the design; and identifies all stakeholders for the execution of the design, including considerations of public health and welfare, and evaluating cultural, social, an environmental consequences.

(SO-2.b) Enumerates limits imposed on the design; identifies risks entailed in the design's development and implementation; and develops design specifications, quantified where possible, using technical/professional engineering codes as appropriate.

(SO-2.c) Ideates multiple candidate solutions; and systematically evaluates engineered design options corresponding to these multiple candidate solutions w.r.t. design specifications and constraints.

(SO-2.d) Validates the design, where appropriate, by creating a physical prototype, and/or verifying the engineered solution through analysis, computer simulation, and a suitable testing regimen of the prototype.

(SO-2 note. The 10 underlined phrases correspond to the "10 Steps of Design Thinking" enumerated on the MIT professional-education website.)

SO-3 "An ability to communicate effectively with a range of audiences. "

(SO-3.a) Writes effectively on engineering topics for diverse technical and nontechnical readers.

(SO-3.b) Speaks effectively on engineering topics to diverse technical and nontechnical audiences.

(SO-3.c) Produces clear, complete, and accurate technical graphics.

SO-4 "An ability to recognize ethical and professional responsibilities in engineering situations, and make informed judgements which consider the impact of engineering solutions in global, environmental, and social contexts."

(SO-4.a) Adheres to academic honesty codes in studies of engineering and other subjects.

(SO-4.b) Demonstrates familiarity with, and commitment to abiding by, professional-engineering codes of ethics.

(SO-4.c) Responsibly considers societal, economic, and environmental impacts (at local, regional, and global scales) in assessing engineering solutions and projects.

SO-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."

(SO-5.a) Collaborates effectively on a team, including contributing leadership as needed, planning tasks, establishing goals and meeting objectives.
(SO-5.b) Collaborates effectively and inclusively on a team with diverse backgrounds, skills, or agendas.

SO-6 "An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions."
(SO-6.a) Conducts experiments, including the verification and calibration of the instrument.
(SO-6.b) Analyzes data and communicates the results with accuracy and integrity.
(SO-6.c) Devises and carries out experimental procedures for quantifying either (i) a process, or (ii) the performance of an engineered device.

SO-7 "An ability to acquire and apply new knowledge as needed, using appropriate learning strategies."
(SO-7.a) Devises and implements an intentional and systematic process for acquiring new knowledge, using learning strategies consistent with the topic under study.
(SO-7.b) Strategically applies new knowledge to situations or problems rendered tractable by the new knowledge and which were formerly out of scope.
(SO-7.c) Devises and communicates an original conceptual framework for the application of existing knowledge in a novel context or situation.

APPENDIX B
SAMPLE SURVEY FOR SO-7 ASSESSMENT

Dear student:

The **purpose** of this survey is to determine whether you needed to teach yourself new (extracurricular) knowledge for this class.

There are **no right or wrong answers** and your responses will be anonymous

I. I am a: ( ) graduate student ( ) undergraduate student ( ) other

II. My degree program is:

( ) bioengineering ( ) civil engineering ( ) electrical engineering ( ) mechanical engineering
( ) engineering -- general ( ) environmental ( ) industrial and systems engineering

PART (A) Did you **need to teach yourself "extracurricular knowledge"** to complete an assignment?

III. To complete at least one assignment in this class, did you need "extra-curricular" knowledge? (choose one)

1 Everything I needed to do the assignments was taught in this class or another course I have taken.
2 I needed to re-teach myself some topics from other courses to complete the assignments.
3 I chose to learn new knowledge (beyond my coursework) to do an assignment, but it was not required.
4 I **chose** to learn new knowledge (beyond my coursework) to complete an assignment for a better grade.
5 I had to learn new knowledge (beyond my regular coursework) to complete at least one assignment.

If you answered 1 or 2 you are done! Otherwise, answer questions **IV** and **V.**

IV. The resources I used to learn the new knowledge included: (pick one rating for each resource)

		Not used	Not useful	←	Useful	→	Essential
1	Online videos including YouTube	0	1	2	3	4	5
2	Other online resources (tutorials, Q/A exchange boards, Wikipedia)	0	1	2	3	4	5
3	Discussions with my professor and/or classmates	0	1	2	3	4	5
4	Consultations with experts or professionals in the field	0	1	2	3	4	5
5	Technical/professional literature (texts, journals, professional codes).	0	1	2	3	4	5

V. My success in applying the new knowledge to complete the assignment was: (pick one)

1 Not successful
2 Partially successful
3 Adequate to the problem at hand
4 Quite successful
5 Key to interpreting the implications of the assignment