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A faculty-directed Continuous Improvement regimen with intentional ABET/SO 1-7 scaffolding

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Abstract.
To comply with ABET/EAC Accreditation Criterion 4, engineering Programs must carry out regular documented procedures for assessing and enhancing student attainment in that Program's student outcomes. Furthermore, the Program's student outcomes must include the seven ABET/EAC Student Outcomes, SOs 1-7, which are enumerated in ABET/EAC Accreditation Criterion 3. These regular documented procedures, for assessing and enhancing student attainment in the Program's designated student outcomes, are collectively denoted "Continuous Improvement" (CI).

A practical, faculty-managed CI regimen was recently adopted by our institution's BS ME Program. The core building block of this CI scheme are its seven SO committees, one for each ABET/EAC SO. Each SO committee consists of three to four faculty, and each committee has broad oversight responsibility for student attainment in its respective SO. The tasks of each SO committee include: (i) characterizing and/or refining the performance indicators for its SO; (ii) selecting a specific summative assessment instrument for each performance indicator in a given academic year; (iii) reviewing and evaluating completed assessments; (iv) analyzing the curricular scaffolding of the SO within the Program; and (v) making specific curricular recommendations, for enhancing student attainment in its SO, to the Program faculty for consideration.

Our Program's CI regimen is facilitated by a program Assessment Coordinator, who convenes the meetings of the seven individual SO committees and documents the respective committees' deliberations and recommendations. The Assessment Coordinator also arranges the specific assessments requested by the SO committees, tabulates the results, and archives samples of the assessments. For direct assessment, the Assessment Coordinator recruits two faculty to separately assess their own personal copy of the same twenty samples of student work; this procedure has elevated the faculty's respect for, and confidence in, the assessment process. The Assessment Coordinator also documents any CI-relevant discussion that takes place in academic meetings, such as department meeting or college retreats. Finally, the Assessment Coordinator maintains all CI-relevant data in an electronic database, and ensures that documentation needed for Program accreditation is up to date.

Thus far our Program's CI regimen has both engaged the faculty and resulted in several specific curricular adjustments that have enhanced our Program's alignment with the ABET/EAC SO 1-7. Our Program's experience to date will be described in this paper.

0. Overview.

This paper describes a regimen for carrying out "Continuous Improvement" (here on, denoted as CI), a process which is mandated by the ABET/EAC Criteria for Accrediting Engineering Programs (here on, denoted as the Criteria). In our Program's CI procedure there are seven faculty oversight committees, one for each of the ABET/EAC Student Outcomes 1-7 enumerated in Criterion 3 of the Criteria. Our Program's CI regimen is relatively new, having been implemented several years ago, and thus far its benefits have exceeded expectations.

The goal of this paper is to provide sufficient practical specifics so that other programs may build upon our Program's experience. Specifically, the five major components of our CI regimen (i) the seven Student Outcome (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 the success of *any* process for CI depends, first, on establishing clarity for exactly what CI is and why it is of value to the Program. This is discussed first.

1. Understand the fundamental utility of a comprehensive CI regimen for the Program.

Criterion 4 of the Criteria states:

> "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 CI is specifically and solely concerned with student outcomes. CI is a focused activity in which the Program must (i) demonstrate that student attainment in the student outcomes is being systematically measured, and (ii) provide evidence of documented processes for evaluating and abetting this attainment.

Furthermore, Criterion 3 of the Criteria requires a Program's Student Outcomes to be published, and that this list must include the seven ABET/EAC Student Outcomes (SO 1-7).

Because our Program's CI regimen happens to be organized in a quite parallel fashion to SO 1-7, the original SO 1-7 text from the Criteria is reproduced here for subsequent reference (with the boldface type added by the author):

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.

Engineering students who gain genuine facility in the above seven competencies will likely have impactful subsequent careers. Consequently a Program's commitment to systematically foster student attainment in SO 1-7 is a worthy enterprise.

2. Create seven SO oversight committees, one for each ABET 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 each committee has oversight responsibility for the SO in its purview. Specific 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 (the designated individual 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 (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 of the SO committees meet 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 with the goal of keeping the meeting both focused and under an hour.

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 strategy for the 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 1-7 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.

3. Develop performance indicators.

Section **2.** above ("create seven SO oversight committees") described 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 seven 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, and (ii) 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, for illustration, is given in **Appendix A.** (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 in the Criteria.

The second observation applies to programs in transition from the former (pre-2019) SO a-k to the current SO 1-7. ABET/EAC revised the SO's and definitions in the new Criteria with intent, so simply "mapping" existing 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, because this activity will compel 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 this 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 above text did not align well with the overall "professional practice" tone of SO 4. However, the above candidate performance indicator was eventually adopted, 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 sole function of a given performance indicator is to facilitate student attainment in its 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 its SO-2 performance indicators several times, in part owing to the complexity of the SO-2 text, and also due to the Criteria's expanded definition of engineering design. The consequent final set of performance indicators 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 for a given performance indicator in a consistent manner, a scoring device such as a rubric is needed. Under our Program's former CI scheme, faculty were asked to carry out assessment, of all and every type of student work, using a single, common, generic Program-wide set of performance-indicator rubrics. However, generic Program-wide rubrics proved a failure because they were voluminous (pages upon pages of tiny print), confusing to the faculty, and too nonspecific to be effectively applied in practice. So instead, in our current CI regimen, the Program now utilizes assessment-specific rubrics, and these assessment mechanics are described next.

4. Assessment mechanics.

The goal of assessment is to gauge student attainment, upon completion of the Program, in each Student Outcome 1-7. 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. 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: a so-called “indirect assessment” of the performance indicator.

3. A third possibility, though, 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.

4.1 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 take place.

2. After the quiz is collected, but *before* the quiz is graded, the Assessment Coordinator selects twenty quizzes (of confirmed BSME students, 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.

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 exceptional possibilities 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.

4. 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.

5. 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.

6. 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. Knowing that another experienced individual is 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 the above-described "rubric" is more than adequate if (i) the assessment instrument is relatively specific (like a quiz question), and (ii) the two faculty assessors are experienced instructors of the discipline. In short, if two experienced fluid-mechanics instructors score a Bernoulli-equation problem, their respective expectations in the categories of "outstanding," "target," "baseline," etc., will likely prove consistent. 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) an actual 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 mutuallydevised 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 is generally 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 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.

4.2 Indirect assessment mechanics.

In the inaugural year of our Program's then new (now current) CI regimen, the Assessment Coordinator conducted an "indirect assessment" (i.e. a student survey) "in parallel" for every direct assessment carried out as a second, confirmational 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 "parallel 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 as it is (a common explanation for the low response rate when online surveys are deployed). Consequently, SO committees now elect to carry out an "indirect assessment" (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 BS ME Program, the most likely candidate classes where students may need devise appropriate learning strategies to acquire new ("extra curricular") knowledge are their four upper-level technical elective courses, because these classes are often cross-disciplinary or of a professional focus. However, given the broad diversity of 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.

Currently, our technical-elective instructors are not required to give assignments for which students must teach themselves new knowledge, and thus the goal of the SO-7 committee's survey was simply to gauge whether SO-7 experiences were organically occurring in these classes. But unsurprisingly, having conducted the SO-7 survey, the technical-elective faculty responded in subsequent semesters by creating assignments wherein students needed to learn and apply extra-curricular knowledge. In short, the process of using an assessment to gauge SO-7 attainment ultimately nudged the SO-7 attainment forward, just by attempting to measure it.

Beyond committee-developed surveys, our Program's SO 1-7 committees also utilize surveys developed by third parties. One example is CATME (Comprehensive Assessment of Team Member Effectiveness; https://info.catme.org/), which is a suite of online software tools used to assess teamwork; here, our SO-5 ("teamwork") committee utilizes the online peer-assessment tool to survey senior-design teams in their last semester of the capstone-design project. As another example, the SO-4 ("profession ethics") committee devised a variant of a survey described in Carpenter *et al* (2010) [1] to gauge student attitudes towards cheating; this survey is conducted in the first semester of our three-semester capstone-design course sequence.

4.3 When no suitable assessment can be identified for a performance indicator.

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 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.

5. Carry out continuous-improvement documentation.

As required in 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 of the discussions in every SO 1-7 committee meeting bear directly on SO attainment in the Program.

On the other hand, recording the nuggets of CI-specific discussion that transpire in other types of academic meetings (e.g. department or college) is problematic, because the core agenda topics are not necessarily specific to SO attainment; indeed, often there is just a passing remark in a meeting, 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 aspect 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 Department semester review of course sections

6. Develop a comprehensive archive for assessment and continuous improvement.

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 now it hard to imagine managing the BS ME 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.

6.1 ABET/SSR Repository.

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

The "SSR" (for "self-study report") portion of 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.

6.2 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.

6.3 Department 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.

7. 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. (There is also the third (iii) incentive that meetings occur no more than twice a year and are usually kept to an hour!) 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 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 the Program administrator (here, the Mechanical Engineering 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

[1] D.D. Carpenter, T.S. Harding and C.J. Finelli, "Using research to identify academic dishonesty deterrents among engineering undergraduates," *Int. J. Engng. Ed.*, vol.26, no,5, pp 1156-1165, 2010.

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 quantify whether you needed to teach yourself "new knowledge," knowledge that was not covered in any of your classes (including this course), in order to complete one or more assignments in this course.

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
( ) engineering -- general ( ) environmental engineering ( ) mechanical engineering ( ) systems and industrial engineering

III. To complete at least one assignment in this class, did you need "extra-curricular" knowledge? (circle the answer which is consistent with your experience

1. Everything I needed to complete the assignments was taught either in this class or in some other 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 regular coursework) to complete at least one assignment, but it was not required.
4. I chose to learn new knowledge (beyond my regular coursework) to complete at least one 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"** to question **III., you are done!** Otherwise, complete questions **IV** and **V)**

IV. The resources I used to learn the new knowledge included: (circle a number for each type of resource)

		Not used	Not useful ←		Useful	→	Essential
1	Online videos including YouTube	0	1	2	3	4	5
2	Other online resources (e.g. tutorials, blogs, 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 (e.g. texts, reports, journals, professional codes).	0	1	2	3	4	5
6	Other:____________________	0	1	2	3	4	5

V. My success in applying the new knowledge to complete the assignment was: (circle the answer which was consistent with your experience)

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