"EMbedding" the KEEN Framework: An Assessment Plan for Measuring ABET Student Outcomes and Entrepreneurial Mindset

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Estell currently serves as an ABET Commissioner and as a subcommittee chair on ABET’s Accreditation Council Training Committee. He was previously a Member-At-Large on the Computing Accreditation Commission Executive Committee and a Program Evaluator for both computer engineering and computer science. Estell is well-known for his significant contributions on streamlining student outcomes assessment processes, and has been an invited presenter at the ABET Symposium on multiple occasions. Estell is also a founding member and current Vice President of The Pledge of the Computing Professional, an organization dedicated to the promotion of ethics in the computing professions.

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Introduction and Motivation

The computer science program at Ohio Northern University (ONU) is in the process of incorporating the entrepreneurial mindset across its curriculum. As described by the Kern Entrepreneurship Education Network (KEEN) Framework [1], the outcomes of the entrepreneurial mindset – consisting of Curiosity, Connections, and Creating Value – are expressed through both Collaboration and Communication, and are founded on Character. Members of ONU’s engineering faculty have previously expanded upon the KEEN Framework by developing a list of 52 “specific, authentic learning objectives” that are referred to as the “extended KEEN Student Outcomes” (eKSOs) [2], [3]. Collectively, these learning objectives were designed to translate the big picture of the KEEN Framework into smaller, actionable items that could enable more intentional scaffolding of the entrepreneurial mindset throughout that institution’s curricula.

When reviewing the set of eKSOs, it was noted that the learning objectives contained therein were actually performance indicators: specific, measurable statements that help identify required student performance. When subsequently mapped to the recently updated ABET Student Outcomes for engineering programs [4], a significant number of the learning objectives aligned with several of the student outcomes; an even stronger alignment was observed with the ABET Student Outcomes for computing programs [5]. As ONU’s computer science program already needed to modify its assessment plan to be compliant with the recent changes to the ABET Criteria, an interesting question was raised: could the eKSOs be readily incorporated into an assessment plan, thereby allowing for the assessment of both the ABET and KEEN Student Outcomes through a combined process?

It should be noted before continuing on that ONU’s computer science program uses the Faculty Course Assessment Report (FCAR) methodology [6]-[9] for reporting and evaluating assessment data. As this methodology has worked well over multiple accreditation visits, it is not being changed, nor are the program’s evaluation methods. This paper focuses on how the assessment process was updated and streamlined to meet current and known future needs.

Background - Updated ABET Student Outcomes

In 2009, ABET began harmonizing several criteria across all four of its commissions; specifically, the criteria related to students (Criterion 1), program educational objectives (Criterion 2), continuous improvement (Criterion 4), facilities (Criterion 7), and institutional support (Criterion 8). During this process, it was recognized by the Engineering Accreditation Commission (EAC) Criteria Committee that their program outcomes (Criterion 3) had not been reviewed since their original formulation in the mid-1990s [10], [11]. As the EAC was also receiving constituent requests to include additional outcomes, and that a substantial percentage of cited shortcomings were associated with Criterion 3, the EAC convened a task force to begin a
review process. In July 2014 the EAC posted the proposed revisions on the ABET website for constituent review and comment. After an extended review process resulting in some modifications to the proposal, the new Criteria was approved by the ABET Engineering Area Delegation in October 2017, for implementation in the 2019–20 accreditation review cycle. Included were significant revisions to Criterion 3, which required all EAC-accredited programs to reappraise their assessment plans in light of the focus morphing from “a-k” to the following: (1) engineering problem solving, (2) engineering design, (3) communication skills, (4) professional responsibility, (5) teamwork and project management, (6) measurement, testing, and quality assurance, and (7) professional growth.

The Computing Accreditation Commission (CAC) had a different issue, in that instead of an explicit set of outcomes they had their “a-i” list of characteristics that needed to be enabled. This engendered much confusion, especially at institutions where there were also EAC-accredited programs, sometimes housed within the same department. This commission followed a similar, yet less contentious, path to revise their Criterion 3, eventually adopting a set of five required outcomes in place of the aforementioned characteristics. These outcomes, while not harmonized, are in substance topically aligned with the first five EAC student outcomes. The new CAC Criteria, approved in October 2017, was required to be implemented by all accredited programs by the 2019–20 accreditation review cycle. Given the switch from enabling required characteristics to a provided set of required student outcomes, essentially all CAC-accredited programs needed to revise their assessment plans to maintain compliance.

Background – KEEN Network and Framework

The Kern Family Foundation was established in 1998 by Robert D. and Patricia E. Kern, founders of Generac Power Systems, one of the world’s largest manufacturers of complete engine-driven power generator systems [12]. The Foundation focuses on three major program areas, one of which is the Kern Entrepreneurship Education Network – better known as KEEN. As stated on their web site, “[t]he mission of KEEN is to graduate engineers with an entrepreneurial mindset so they can create personal, economic, and societal value through a lifetime of meaningful work” [13]. A network of faculty at approximately 50 institutions believe that it is critical to equip engineers with both a technical skillset and an entrepreneurial mindset fostering curiosity, connections, and creating value – the “3C’s” of the entrepreneurial mindset as defined as part of the KEEN Framework [1] – with the expectation that students will:

- demonstrate constant curiosity about our changing world and explore a contrarian view of accepted solutions,
- integrate information from many sources to gain insight and assess and manage risk, and
- identify unexpected opportunities to create extraordinary value and persist through and learn from failure.

KEEN goes on to state that “[f]raming educational outcomes with an entrepreneurial mindset that is coupled with engineering thought and action – expressed through collaboration and communication – and founded on character equips engineering students to contribute to a flourishing society.”
Alignment of ABET Outcomes and Entrepreneurial Mindset

The concept of relating entrepreneurial mindset to the ABET student outcomes is hardly a radical one, given that entrepreneurial mindset has, to some extent, been already embedded into the ABET Criteria. In their book on teaching the entrepreneurial mindset to engineers, Bosman and Fernhaber dedicate a chapter toward the relationship between the ABET student outcomes and the entrepreneurial mindset [14] where they posit a categorization schema for the old EAC (a)-(k) student outcomes, and then as an example illustrate how Student Outcome (c) aligned with the desire for value creating opportunities via technical feasibility, customer desirability, and business viability. In Figure 1, this concept has been applied to a deconstruction of the new (and similar) EAC Student Outcome 2, but modified to incorporate the four dimensions expressed by Kriewall and Mekemson in their seminal paper of instilling the entrepreneurial mindset: technical fundamentals, customer awareness, business acumen, and societal values [15]. Through such deconstructions, it is evident that the ABET EAC Criteria aligns well with the concept of developing entrepreneurial mindset as part of an engineering curriculum.

![Diagrammed Analysis of ABET EAC Student Outcome 2](image)

Critical Observations

While all programs within the College of Engineering at Ohio Northern University needed to revise their assessment plans to align with the recent changes to the ABET CAC and EAC Criteria, the three programs within the Electrical & Computer Engineering and Computer Science Department, including computer science, each decided to come up with a new set of performance indicators for their respective student outcomes. This decision was not taken lightly. It was felt that this approach would take into account the curricular changes that had taken place since the last update to the assessment plans were made over a decade ago, and would also foster greater buy-in from the faculty, the majority of whom in the department were hired after the previous assessment plan was developed. However, while the engineering programs in the department decided to write all of their performance indicators from scratch, the computer science program took a different approach.

There were two “Aha!” moments that critically shaped the development of the CS assessment plan. As mentioned earlier, the first occurred when examining the list of 52 eKSOs and realizing that they were performance indicators, some with a noticeable degree of alignment to indicators typically used in assessing ABET Student Outcomes. By choosing those eKSOs that exhibited...
such alignment, the program could form the nucleus of an assessment plan that could serve two masters. The second occurred when, during consideration of revisions to the computer science curriculum, the program consulted the materials provided with the Computer Science Curricula 2013 (CS2013) Final Report [16]. The ACM/IEEE-CS Joint Task Force in charge of developing this Report conveniently developed a curricular exemplar template spreadsheet [17] that included on one sheet a large set of “learning outcomes,” a portion of which is shown in Figure 2. These outcomes – 1,110 in all – are organized into one of 18 knowledge areas (KA – column A) by both knowledge unit (KU – column B) and one of three possible mastery levels (Level – column D). These levels, with the number of learning outcomes for each within parentheses, are as follows:

- **Familiarity** (583) concerns a basic awareness of a concept;
- **Usage** (375) is the ability to apply a concept in a concrete way;
- **Assessment** (152) indicates a level of mastery that involves the ability to select an appropriate approach from understood alternatives.

![Figure 2. Portion of ‘LearningOutcomes’ sheet in CS2013 ‘CurriculumExemplarTemplate’ Excel file.](image)

Although developed to more readily allow a program to map their curriculum against the CS2013 Body of Knowledge, no computer science program is expected to implement all of these learning outcomes; in fact, only 253 address what are referred to as “Tier 1” requirements, whereas nearly half (550) address purely elective content. While examining this sheet, it was noted that, by filtering down to just the 152 rows containing the “Assessment” learning outcome level, one arrived at a significantly smaller set of potential performance indicators.

With these two realizations, the problem of selecting a set of performance indicators for an assessment plan went from a theoretically infinite number of statements that the faculty could have written on their own to a much more manageable, and already written, set of 204 statements for review and consideration. Needless to say, leveraging the work of many others, including a Body of Knowledge document produced via an iterative and constituent-engaging process by two major professional societies in the field of computing, had a major impact in making the next four steps of the process much easier and less time consuming for all concerned.
Step 1: Selection of ABET Performance Indicators from eKSOs Materials

The critical task at hand for the program was ensuring that the new assessment plan satisfactorily aligned with the ABET Criteria; thus, the program started selecting performance indicators based on the extent to which they supported the ABET CAC Student Outcomes. The first step was to begin the population of the assessment plan with performance indicators obtained directly from the eKSOs. Fortunately, a mapping tool (provided in Appendix A) demonstrating strong correlations between the eKSOs and the ABET EAC Student Outcomes was available for use. This tool was created by the author (a former CAC Executive Committee member) and Patsy Brackin (a former EAC Criteria Committee Chair), and subsequently provided as part their workshops on using entrepreneurial mindset to demonstrate ABET Student Outcomes [18], [19].

This mapping indicates what are considered as strong correlations between the eKSOs and the ABET outcomes. However, this is meant to serve only as a first-order “back of the envelope” approximation to help jump-start one’s discernment and discussion process: some of these strong correlations might not be present for one’s program, whereas others left unmarked might resonate strongly. Workshop participants were thus encouraged to use a moderated discernment process when taking the process back to their institutions by focusing on just one of the six eKSOs categories at a time and discussing the resultant mapping to the ABET EAC 1-7 outcomes (or, as previously mentioned, the aligned CAC 1-5 outcomes) as evidenced by their program. By breaking the categories of Curiosity, Connections, Creating Value, Collaboration, Communication, and Character into separate units, one enables a more intentional, thoughtful consideration of the scaffolding of the entrepreneurial mindset throughout the curriculum. While the faculty use a category-centric mapping matrix similar to that shown in Figure 3 for their discussions, the moderator has the option of referring to the developed mapping tool for guidance in steering the conversations toward potential solutions and away from developing dense matrices through tenuous associations or tortured logic.

<table>
<thead>
<tr>
<th>ONU Extended KEEN Student Outcomes: Connections (Performance Indicators)</th>
<th>ABET Student Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Understand ramifications (technical and non-technical) of design decisions.</td>
<td>1 2 3 4 5 6 7</td>
</tr>
<tr>
<td>b. Identify and evaluate sources of information.</td>
<td></td>
</tr>
<tr>
<td>c. Connect life experiences with class content.</td>
<td></td>
</tr>
<tr>
<td>d. Connect content from multiple courses to solve a problem.</td>
<td></td>
</tr>
<tr>
<td>e. Integrates/synthesizes different kinds of knowledge</td>
<td></td>
</tr>
<tr>
<td>f. Consider a problem from multiple viewpoints.</td>
<td></td>
</tr>
<tr>
<td>g. Persuades why a discovery adds value from multiple perspectives</td>
<td></td>
</tr>
<tr>
<td>h. Articulates the idea to diverse audiences</td>
<td></td>
</tr>
<tr>
<td>i. Understands how elements of an ecosystem are connected</td>
<td></td>
</tr>
<tr>
<td>j. Identifies and works with individuals with complementary skill sets, expertise, etc.</td>
<td></td>
</tr>
<tr>
<td>k. Develop a professional network.</td>
<td></td>
</tr>
</tbody>
</table>

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

**Figure 3. Connections mapping matrix and associated ABET EAC Student Outcomes.**
Ideally, the moderator focuses faculty discussion on finding “meaningful” content coverage and associated student work artifacts—something more substantial than just a cursory mention and a related homework question. When applied, the concepts of having at least “a full lecture” or “an entire lab session” appears to resonate best in terms of defining a lower bound to what constitutes “meaningful”. Given that there are other levels of discernment later in the process, there’s not a compelling need at this stage for a highly rigid definition, other than to set an appropriate threshold to eliminate one source of “noise” from the assessment process by (hopefully) preventing spurious claims made to justify a course’s importance by claiming it enables the attainment of an extensive number of the listed performance indicators. All performance indicators obtained from this expanded framework are referenced within the assessment plan by the format (eKSOs Category - Letter); for example, the source of the performance indicator “Develop a professional network” in row k of Figure 3 would be referenced by the use of “(Connections-k)” within the assessment plan.

Step 2: Selection of Performance Indicators from CS2013 Materials

The next step in developing the assessment plan was to find relevant performance indicators from the “LearningOutcomes” tab in the CS2013 “CurriculumExemplarTemplate” spreadsheet. Initial efforts involved filtering the list to show only those outcomes at the Assessment level, then examining each to determine if it aligned with the program’s curriculum. In a few cases where none of the filtered learning outcomes seem to fit, the review was expanded to examining similar knowledge unit outcomes listed under the other two mastery levels. All performance indicators obtained from the CS2013 spreadsheet are referenced from the identifying information contained in columns A, B, and E via the format (Knowledge Area – Knowledge Unit - Number); if the numerical reference is immediately followed by a letter, this indicates that the learning outcome was classified at either the Usage (u) or Familiarity (f) mastery level. Performing steps 1 and 2 resulted in the program having a set of proposed performance indicators aligned to the ABET Student Outcomes and a corresponding list of courses from which to draw assessment data from. Figure 4 shows an example from the initial version of the resulting assessment plan; course names are abbreviated to save space within each content list.

| CAC Student Outcome 5: Graduates of the program will have an ability to function effectively as a member or leader of a team engaged in activities appropriate to the program’s discipline. |
|---|---|---|
| **Sub-Outcome** | **Performance Indicators** | **Content Courses** |
| A. Facilitate team capabilities by valuing diversity. | i. Identify and justify necessary roles in a software development team. (SE-Software Project Management-3a) | Pgm2, SwEn, CapDE1, CapDE2 |
|  | ii. Recognize their own strengths, skills, and weaknesses, as well as those of others. (Collaboration-8) | Pgm2, PjDev, CapDE1, CapDE2 |
|  | iii. Be able to network and see the value of others. (Collaboration-9) | Orient, PjDev, CapDE1, CapDE2 |
| B. Build trust through open lines of communication. | i. Understand the sources, hazards, and potential benefits of team conflict. (SE-Software Project Management-4a) | Design1, Pgm2, SwEn, PjDev, CapDE1, CapDE2 |
|  | ii. Be able to teach and learn from peers. (Collaboration-3d) | Design1, MbApDev, DSA2, SwEn |
|  | iii. Be aware of and able to work through interpersonal conflicts. (Collaboration-4a) | Design1, Pgm2, CapDE1, CapDE2 |
| C. Produce results by being a supportive team member. | i. Meet commitments. (Character-6) | Pgm2, MbApDev, SwEn, UID, PjDev, CapDE1, CapDE2 |
|  | ii. Accept responsibility for their own actions, and credit the actions of others. (Character-9) | PjDev, CapDE1, CapDE2 |

**Figure 4. Example of course mapping to performance indicators.**
Step 3: Refining the Assessment Plan

When creating an assessment plan, one needs to aim for a “sweet spot” such that sufficient data is collected to allow the program to make informed decisions, but not so much that faculty members – especially assessment coordinators – feel overwhelmed from having massive amounts of data to process. There are two tools that can help with iterating through such a refinement process: the “PreCAR” and the Course Assessment Matrix.

PreCAR

The PreCAR – short for “Preliminary to the FCAR” – is the name given to a variation of the FCAR reporting tool, in that each course is represented by an Excel file containing all of the content that the course instructor identifies as pertaining to one or more of the performance indicators. It thus serves as a precursor to the FCAR, and is meant to be consulted prior to teaching the course so that the instructor is aware of what artifacts need to be available for the assessment process. Figure 5 illustrates an example PreCAR.

![Figure 5. PreCAR Example](image)

The PreCAR is used to list all course attributes with artifacts that relate to the performance indicators, regardless of whether or not they are used for assessment. The reason for maintaining these extra rows is that the evaluation of an outcome might point to shortcomings related to a specific indicator and/or a specific course. In such cases, additional measures can readily be identified as part of an action item for examining the issue in greater detail.

In constructing the PreCAR, the instructor needs to identify, roughly, the artifact from which assessment data is to be drawn. As part of this process, it is possible that the instructor will realize that something was erroneously added to the assessment plan for a variety of reasons (for example, someone accidently referenced the wrong course, realized that the coverage of a topic is cursory, etc.), or (albeit less likely) that something meaningful was overlooked. This is not a problem – assessment plans can be viewed as living, breathing documents that can be modified as appropriate, especially as the development of an assessment plan is usually an iterative process where entries are usually double-checked, and often triple-checked, to avoid errors.
There is always the danger that a program, for whatever reason, might get “assessment happy” and attempts collecting an overabundance of data (note: this should not be construed as an argument for a minimalist set of data). One way of successfully dealing with assessment overkill is to establish a rule that three measures per performance indicator should be sufficient under normal circumstances in determining the extent to which that indicator is being attained. This constraint can then be used in selecting what courses will contribute data to the assessment plan through means of the Course Assessment Matrix: an Excel spreadsheet that lists (as rows) the required courses in the major against (as columns) the performance indicators contained in the assessment plan. Figure 6 illustrates a relevant portion of the Course Assessment Matrix developed for the ONU computer science program’s assessment plan.

![Figure 6. Portion of Course Assessment Matrix](image)

The cells containing characters at an intersection between a required course row and a performance indicator column indicates a place where assessment data is available. Initially, all such cells are marked with the letter ‘X’ and the number of possible assessments for each course row and indicator column are totaled (by using Excel’s COUNTA function) and displayed. As the assessment coordinator begins the process of determining where data is to be collected, the letter ‘A’ (for “assessed”) is used to replace the ‘X’ to denote where reporting selections have been made. A second set of counter cells are set up (via the COUNTIF function) to track the data pulls for each indicator and the resultant course assessment load. As the design heuristic is based on limiting the amount of data reported for each performance indicator to no more than three courses, the columns reporting the fewest number of courses enabling their indicator receive prioritized attention. This allows the coordinator to see the course reporting loads prior to processing those indicators where there are many courses to choose from, thereby helping to spread the assessment workload across all required courses, and to those who teach those courses. However, there are some required courses, such as first-year cornerstone and senior-year capstone, that naturally lend themselves toward being assessment collection magnets.
At this point faculty are asked to review the Course Assessment Matrix in terms of performing the indicated assessment in their courses by consulting their PreCAR information, after which the plan is discussed and reviewed in one or more assessment meetings. This usually results in an iterative process where course instructors are repeatedly vetting the performance indicators obtained from both the eKSOs and CS2013 sources against their program’s curricular content. Consequently, some proposed assessment locations are removed while others are added, and some performance indicators might undergo minor wordsmithing to strengthen their curricular alignment while others might be removed entirely if it is felt that the remaining data collected for the corresponding student outcome will suffice for making informed decisions. Once this reviewing process reaches some semblance of a steady-state, the plan is finalized; the “Content Courses – Assessed” columns of the Assessment Plan document (Figure 4) and the “Assessed in Plan?” columns of all PreCAR documents (Figure 5) are updated accordingly.

Appendix B provides the final list of sub-outcomes and performance indicators selected for assessing the ABET CAC Student Outcomes by the computer science program at Ohio Northern University through the processes described in this paper. Of the 43 performance indicators used in this assessment plan, 19 are from the eKSOs; these indicators are italicized in this appendix. Table 1 illustrates the breakdown of support for each Student Outcome from the eKSOs and CS2013 resources; Outcome 6 is defined within the CAC’s Program Criteria for accrediting computer science programs [5].

<table>
<thead>
<tr>
<th>CAC Student Outcome</th>
<th>CS2013</th>
<th>eKSOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (apply computing principles)</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>2 (design to meet requirements)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>3 (communicate effectively)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>4 (professional responsibilities)</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5 (function effectively on a team)</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>6 (apply CS theory to solutions)</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>

**Step 4: Using CS2013 Performance Indicators to Enhance the eKSOs**

Once the computer science program reached the point of having the assessment plan finalized from an ABET perspective, the decision was made to augment the measure of the KEEN Student Outcomes by examining the selected CS2013 performance indicators and determining if they effectively mapped to one of the six KEEN outcome categories. The developers of the eKSOs actually encourage such additions by listing the following as the last performance indicator in each category [2]:

“[Other student learning outcomes of your own design.]”

Such an examination can only serve to benefit the assessment of the entrepreneurial mindset, as the program is already planning on collecting that assessment data for ABET. Additionally, by constraining the examination of the CS2013 learning outcomes to just those already selected for use in the assessment plan, the workload for determining the entrepreneurial mindset performance indicators is minimized. As there are only 24 such performance indicators to be examined, this proved to be an almost trivial process.
Appendix C provides the final list of performance indicators selected for assessing the entrepreneurial mindset through use of the KEEN Framework. As this list is a subset of the performance indicators listed in Appendix B, the references to the ABET Student Outcomes are provided within brackets. Of the 31 performance indicators contained in this assessment, 12 were obtained from the list of selected CS2013 learning outcomes; these indicators are shown italicized in this appendix. Table 2 illustrates the breakdown of support for each enhanced KEEN Student Outcome Category from either the eKSOs or CS2013 resources.

<table>
<thead>
<tr>
<th>eKSOs Category</th>
<th>CS2013</th>
<th>eKSOs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curiosity</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Connections</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Creating Value</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Collaboration</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Communication</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Character</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

The one noticeable issue resulting from this stage of this process is that only two performance indicators are being used for measuring Curiosity, whereas the remaining categories all have at least five associated indicators. Given that the computer science program at Ohio Northern University is in the process of modifying some of its courses to instill the entrepreneurial mindset within its curriculum, this result was an unexpected bonus, as it is pointing out an area where further curricular development is potentially needed. A secondary bonus is that the Curiosity-related eKSOs can be used as a guide for determining and developing this additional curricular material.

Assessment Reporting

As mentioned earlier, the computer science program at Ohio Northern University employs the Faculty Course Assessment Report (FCAR) to document the assessment data collected for the ABET-related performance indicators within each of its courses. One of the sections within each FCAR is dedicated to reporting on Student Outcome Assessment; an example of what is provided as a datum is shown in Figure 7.

<table>
<thead>
<tr>
<th>Student Outcome Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CS 2.C.ii</strong> Use a variety of techniques to evaluate a given UI.</td>
</tr>
</tbody>
</table>

Students learned how to apply techniques such as Gestalt design principles, Dieter Rams’ rules regarding good design, and Fitts Law to the analysis of user interfaces. Source: Final Exam Questions 5, 6, and 16. EAMU vector: (5, 4, 1, 1).

As the other programs in the Electrical & Computer Engineering and Computer Science Department also employ the FCAR, and as some of the courses in the department are required in multiple curricula, the performance indicators are prefaced by the appropriate discipline abbreviation; in this case, “CS” is used for computer science. Next is the shorthand reference
indicating that this datum is in support of the second (“ii”) performance indicator used for the third (“C”) sub-outcome for ABET (CAC) Student Outcome 2, followed by the stated performance indicator. (The concept of sub-outcomes has been adopted by programs as a means to better differentiate particular aspects of each Student Outcome for a more targeted assessment and evaluation process.) The instructor then briefly describes how this indicator relates to the course, documents the source of the assessment, and then reports the results in the form of an “EAMU” vector [20]. This rules-based performance vector represents a count of the number of students that rated at Excellent, Adequate, Minimal, and Unsatisfactory performance levels in the evaluation of this particular assessment artifact. The rules are often, but not necessarily, applied through use of either rubrics or by specifying scoring levels for each category, typically defined by 90% and above being considered excellent, 75%-89% adequate, 60%-74% minimal, and below 60% unsatisfactory [7]. This vector is then fed into the overall assessment and evaluation processes for the program, which can be implemented in a variety of modes from spreadsheets [6] to fully automated systems [9], [21] to report the extent to which each performance indicator is being attained, and thence evaluate the extent to which each student outcome is being attained.

Discussion

“Remember,
A tree that fills a man’s embrace grows from a seedling
A tower nine stories high starts with one brick
A journey of a thousand miles begins with a single step”
— Lao Tzu, *Tao Te Ching* [22]

The above quote, originally written over two millennia ago, states the truism that even the longest and most difficult ventures have a starting point. The road to creating a new assessment plan often appears intimidating, discouraging many from taking that first step. It takes time to implement such plans, due to the introspective nature of constructively examining one’s curriculum and the iterative nature of systematically developing the plan, and it is too often the case that a program has no map of this journey to follow. The reluctance to get started is often the greatest challenge faced by a program, especially by intimidated junior faculty who have not yet faced the baptism of their first ABET accreditation site visit and by senior faculty who might opine that such plans only need developing once. However, while there are challenges when travelling along such a road, various opportunities – some expected, others unexpected – will also be encountered.

Probably the greatest challenge to adopting this methodology is that not all disciplines have the benefit of a Body of Knowledge document from which a program can draw a set of performance indicators. The ONU computer science program was fortunate in this respect, as the discipline has had a sequence of such documents starting with the publication of *Curriculum 68* over fifty years ago [23]. Additionally, the CS faculty observed firsthand the difficulties faced by their electrical engineering colleagues with not having such a document developed by, and available from, their professional society. There have been attempts at developing a “pan-engineering” document, most notably by the National Society of Professional Engineers in 2013 [24], [25]; however, while 13 attributes and 30 capabilities were identified, nothing to date in the form of performance indicators has evolved from this initiative. Reviving and moving forward with this particular initiative might be an opportunity worth pursuing.
Another challenge is the relative disparity between the CS2013 Body of Knowledge and the enhanced KEEN Student Outcomes, in that the CS2013 materials are “mature”, having been developed over time in a deliberative, iterative process providing many opportunities for gathering input across the field of computing, whereas the eKSOs were insularly developed by a subset of engineering faculty at one institution and have not been vetted through an equivalent external reviewing and refinement process. By their own admission, the list contained with the eKSOs “is not meant to be definitive, but rather the interpretation of the KEEN framework” at their institution [2]. Accordingly, what works for one institution might not be readily transferrable to others.

Sometimes opportunity presents itself in unexpected ways, such as when a casual conversation held while participating in a 10K race morphs into a collaborative research project presented at ASEE the next year [26]. Similarly, one reviewer’s comment on the draft manuscript for this paper pointed to one aspect of the broader impact of the research contained herein: “that entrepreneurial outcomes can be achieved in existing engineering curricula through revisiting the existing outcomes or minor modifications.” The research contained within this paper has demonstrated a connection between entrepreneurial mindset and the ABET Student Outcomes. An appropriate selection of performance indicators can thus be used to help focus attention on the entrepreneurial mindset aspects of one’s program. Subsequent course-level tweaks made to help students attain the outcomes associated with these indicators, such as through the adoption of various educational resource materials published as “cards” by KEEN on their website [27], allow institutions with constrained resources to embed many of the pertinent aspects of the entrepreneurial mindset without having to create a large-scale, and costly, entrepreneurship program.

Another unexpected opportunity was the discovery that the use of a discipline’s Body of Knowledge could identify already-written performance indicators that can augment the performance indicators currently contained in the eKSOs. A worthy follow-up to this research that would broaden its impact would be to examine fully the content of various discipline-specific Body of Knowledge documents, such as the “Learning Outcomes” of CS2013 and the “Demonstrated Ability” associated with each “Cognitive Domain Level of Achievement” listed for the 21 outcomes listed in the Civil Engineering Body of Knowledge [28], and look for discipline-neutral items that could help extend the eKSOs to serve a larger breadth of institutions.

Conclusion

In The Engineer of 2020, the National Academy of Engineering presented their concept of the engineer of the future as someone who could adapt to rapid changes in technology as well as the social, economic, and cultural forces that would affect engineering [29]. As such calls are made, and as our technical knowledge advances, and as our pedagogical practices evolve, our computing and engineering curricula must also change. Thus, our assessment plans need to change accordingly in order to know the extent to which these curricular changes have allowed programs to develop graduates possessing the traits collectively desired. Having one set of already-written performance indicators to select from, plus a process to follow in associating those indicators to student outcomes, helps to make the task less daunting; having two sets, with
one focused on the technical aspects of one’s discipline and the other on elements of the entrepreneurial mindset, made developing an assessment process that combines the ABET Student Outcome assessment plan presented in Appendix B and the subsequent Entrepreneurial Mindset assessment plan presented in Appendix C relatively straightforward.

Overall, the development of the assessment process and plans contained here was a pleasant experience, as the largest headache previously experienced with such development – crafting the performance indicators – was no longer an issue. The program was able to trust and rely on the work of others to come up with meaningful and insightful measures, adopt them as needed, and thus move on, saving the program’s faculty considerable time and effort as a consequence.

Resources

Templates similar to that shown in Figure 3 for assisting programs in developing their own eKSO-based assessment plan, plus all documents associated with the ONU Computer Science program’s assessment plan, have been made available as a Card on KEEN’s Engineering Unleashed web site [30].

References

## Appendix A. eKSOs to ABET Student Outcomes Mapping Tool

<table>
<thead>
<tr>
<th>Ohio Northern University Extended KEEN Student Outcomes</th>
<th>ABET EAC Student Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Develop a propensity to ask MORE questions.</td>
<td></td>
</tr>
<tr>
<td>b. Be able to formulate SALIENT questions.</td>
<td></td>
</tr>
<tr>
<td>c. Question information that is given without sufficient justification.</td>
<td>X</td>
</tr>
<tr>
<td>d. Collects feedback and data from many customers and customer segments.</td>
<td>X</td>
</tr>
<tr>
<td>e. Recognize and explore knowledge gaps.</td>
<td></td>
</tr>
<tr>
<td>f. Critically observes surroundings to recognize opportunity.</td>
<td></td>
</tr>
<tr>
<td>g. View problems with an open mindset and explore opportunities with passion.</td>
<td></td>
</tr>
<tr>
<td>h. Be able to self-reflect and evaluate preconceived ideas, thoughts, and accepted solutions.</td>
<td>X</td>
</tr>
<tr>
<td>i. Explores multiple solution paths.</td>
<td></td>
</tr>
<tr>
<td>j. Gathers data to support and refute ideas.</td>
<td></td>
</tr>
<tr>
<td>k.Suspends initial judgement on new ideas.</td>
<td>X</td>
</tr>
<tr>
<td>l. Take ownership of, and express interest in topic/expertise/project.</td>
<td>X</td>
</tr>
<tr>
<td>m. Observes trends about the changing world with a future-focused orientation/perspective.</td>
<td></td>
</tr>
<tr>
<td>n. Understand ramifications (technical and non-technical) of design decisions.</td>
<td>X X</td>
</tr>
<tr>
<td>o. Identify and evaluate sources of information.</td>
<td></td>
</tr>
<tr>
<td>p. Connect life experiences with class content.</td>
<td></td>
</tr>
<tr>
<td>q. Connect content from multiple courses to solve a problem.</td>
<td></td>
</tr>
<tr>
<td>r. Integrates/synthesizes different kinds of knowledge</td>
<td>X X</td>
</tr>
<tr>
<td>s. Consider a problem from multiple viewpoints.</td>
<td></td>
</tr>
<tr>
<td>t. Persuades why a discovery adds value from multiple perspectives.</td>
<td>X</td>
</tr>
<tr>
<td>u. Articulates the idea to diverse audiences.</td>
<td></td>
</tr>
<tr>
<td>v. Identifies and works with individuals with complementary skill sets, expertise, etc.</td>
<td>X</td>
</tr>
<tr>
<td>w. Develop a professional network.</td>
<td></td>
</tr>
<tr>
<td>x. Identify the needs and motivations of various stakeholders.</td>
<td>X</td>
</tr>
<tr>
<td>y. Express empathy in identifying problems and exploring solutions.</td>
<td>X</td>
</tr>
<tr>
<td>z. Create solutions that meet customer needs.</td>
<td>X X</td>
</tr>
<tr>
<td>aa. Defines a market and market opportunities</td>
<td></td>
</tr>
<tr>
<td>bb. Craft a compelling value proposition tailored to specific stakeholders.</td>
<td>X</td>
</tr>
<tr>
<td>cc. Integrate non-monetary and monetary factors into a triple bottom line assessment.</td>
<td>X X</td>
</tr>
<tr>
<td>dd. Applies technical skills/knowledge to the development of a technology/product</td>
<td>X</td>
</tr>
<tr>
<td>ee. Modifies an idea/product based on feedback</td>
<td>X X</td>
</tr>
<tr>
<td>ff. Focuses on understanding the value proposition of a discovery</td>
<td></td>
</tr>
<tr>
<td>gg. Describes how a discovery could be scaled and/or sustained.</td>
<td></td>
</tr>
<tr>
<td>hh. Engages in actions with the understanding that they have the potential to lead to gains or losses</td>
<td></td>
</tr>
<tr>
<td>i. Recognize their own strengths, skills, and weaknesses, as well as those of others.</td>
<td>X</td>
</tr>
<tr>
<td>j. Be able to lead, delegate, and follow.</td>
<td>X</td>
</tr>
<tr>
<td>k. Be aware of and able to work through interpersonal conflict.</td>
<td>X</td>
</tr>
<tr>
<td>l. Be able to teach and learn from peers.</td>
<td>X</td>
</tr>
<tr>
<td>m. Be able to network and see the value of others.</td>
<td>X</td>
</tr>
<tr>
<td>n. Present technical information effectively (graphs, tables, equations).</td>
<td>X</td>
</tr>
<tr>
<td>o. Identify and organize information in a format suited to the audience.</td>
<td>X</td>
</tr>
<tr>
<td>p. Provide and accept constructive criticism, including self-evaluation.</td>
<td>X</td>
</tr>
<tr>
<td>q. Produce effective written reports.</td>
<td>X</td>
</tr>
<tr>
<td>r. Produce effective verbal presentations.</td>
<td>X</td>
</tr>
<tr>
<td>s. Manage informal communications (meetings, networking, etc.).</td>
<td>X</td>
</tr>
<tr>
<td>t. Set, evaluate, and achieve personal and professional goals.</td>
<td>X</td>
</tr>
<tr>
<td>u. Meet commitments.</td>
<td>X</td>
</tr>
<tr>
<td>v. Recognize &amp; evaluate potential impacts while making informed ethical &amp; professional decisions.</td>
<td>X</td>
</tr>
<tr>
<td>w. Accept responsibility for their own actions, and credit the actions of others.</td>
<td>X</td>
</tr>
<tr>
<td>x. Develop an appreciation of hard work and recognize the benefits of focused and fervent effort.</td>
<td>X</td>
</tr>
<tr>
<td>y. Work toward the betterment of society.</td>
<td>X</td>
</tr>
</tbody>
</table>
Appendix B. Computer Science Assessment Plan for ABET Student Outcomes

eKSOs-derived performance indicators denoted in italics

CAC Student Outcome 1: Graduates of the program will have an ability to analyze a complex computing problem and to apply principles of computing and other relevant disciplines to identify solutions.

A. Analyze a complex computing problem
   i. For an identified user group, undertake and document an analysis of their needs.
   ii. Understand the mapping of real-world problems to algorithmic solutions (e.g., as graph problems, linear programs, etc.).
   iii. In the context of specific algorithms, identify the characteristics of data and/or other conditions or assumptions that lead to different behaviors.
   iv. Perform empirical studies to validate hypotheses about runtime stemming from mathematical analysis.

B. Apply (1) principles of computing and (2) other relevant disciplines to identify solutions.
   i. Consider a problem from multiple viewpoints.
   ii. Determine an appropriate algorithmic approach to a problem.
   iii. Analyze simple problem statements to identify relevant information and select appropriate processing to solve the problem.

CAC Student Outcome 2: Graduates of the program will have an ability to design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of the program’s discipline.

A. Design a computing-based solution.
   i. Identify the needs and motivations of various stakeholders.
   ii. Explores multiple solution paths.
   iii. Explain the relationships between the requirements for a software product and its design, using appropriate models.

B. Implement a computing-based solution.
   i. Applies technical skills/knowledge to the development of a technology/product.
   ii. Modifies an idea/product based on feedback.

C. Evaluate a computing-based solution.
   i. Understand ramifications (technical and non-technical) of design decisions.
   ii. Use a variety of techniques to evaluate a given UI.
   iii. Identify the relative strengths and weaknesses among multiple designs or implementations for a problem.

CAC Student Outcome 3: Graduates of the program will have an ability to communicate effectively in a variety of professional contexts.

A. Demonstrate effective written communication skills.
   i. Identify and organize information in a format suited to the audience.
   ii. Evaluate written technical documentation to detect problems of various kinds.
   iii. Write clear, concise, and accurate technical documents following well-defined standards for format and for including appropriate tables, figures, and references.

B. Demonstrate effective oral communication skills.
   i. Identify and organize information in a format suited to the audience.
   ii. Plan interactions (e.g., virtual, face-to-face, shared documents) with others in which they are able to get their point across, and are also able to listen carefully and appreciate the points of others, even when they disagree, and are able to convey to others that they have heard.
   iii. Produce effective verbal presentations.

C. Demonstrate effective graphical communication skills.
   i. Identify and organize information in a format suited to the audience.
   ii. Present technical information effectively (graphs, tables, equations).
CAC Student Outcome 4: Graduates of the program will have an ability to recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.

A. Recognize professional responsibilities.
   i. Set, evaluate, and achieve personal and professional goals.
   ii. Describe the strengths and weaknesses of relevant professional codes as expressions of professionalism and guides to decision-making.
   iii. Interpret the social context of a given design and its implementation.

B. Make informed judgments based on legal and ethical principles.
   i. Identify contemporary examples of intangible digital intellectual property.
   ii. Recognize and evaluate potential impacts while making informed ethical and professional decisions.

CAC Student Outcome 5: Graduates of the program will have an ability to function effectively as a member or leader of a team engaged in activities appropriate to the program’s discipline.

A. Facilitate team capabilities by valuing diversity.
   i. Identify and justify necessary roles in a software development team.
   ii. Recognize their own strengths, skills, and weaknesses, as well as those of others.
   iii. Be able to network and see the value of others.

B. Build trust through open lines of communication.
   i. Understand the sources, hazards, and potential benefits of team conflict.
   ii. Be able to teach and learn from peers.
   iii. Be aware of and able to work through interpersonal conflict.

C. Produce results by being a supportive team member.
   i. Meet commitments.
   ii. Accept responsibility for their own actions, and credit the actions of others.

CAC Student Outcome 6 [CS Program Criteria]: Graduates of the program will have an ability to apply computer science theory and software development fundamentals to produce computing-based solutions.

A. Applications of computer science theory.
   i. Use big O notation formally to give expected case bounds on time complexity of algorithms.
   ii. Model a variety of real-world problems in computer science using appropriate forms of graphs and trees, such as representing a network topology or the organization of a hierarchical file system.
   iii. Formulate an efficient problem space for a problem expressed in natural language (e.g., English) in terms of initial and goal states, and operators.
   iv. Use subclassing to design simple class hierarchies that allow code to be reused for distinct subclasses.

B. Applications of software development fundamentals.
   i. Choose appropriate conditional and iteration constructs for a given programming task.
   ii. Compare alternative implementations of data structures with respect to performance.
   iii. Analyze the extent to which another programmer’s code meets documentation and programming style standards.
Appendix C. Computer Science Assessment Plan for Entrepreneurial Mindset
CS2013-derived performance indicators denoted in italics

Curiosity
[1.A.i]  For an identified user group, undertake and document an analysis of their needs.

Connections
[1.A.ii]  Understand the mapping of real-world problems to algorithmic solutions (e.g., as graph problems, linear programs, etc.).
[1.B.i]  Consider a problem from multiple viewpoints.
[2.C.i]  Understand ramifications (technical and non-technical) of design decisions.
[4.A.iii]  Interpret the social context of a given design and its implementation.
[6.A.ii]  Model a variety of real-world problems in computer science using appropriate forms of graphs and trees, such as representing a network topology or the organization of a hierarchical file system.

Creating Value
[1.A.iii]  In the context of specific algorithms, identify the characteristics of data and/or other conditions or assumptions that lead to different behaviors.
[2.A.i]  Identify the needs and motivations of various stakeholders.
[2.C.iii]  Identify the relative strengths and weaknesses among multiple designs or implementations for a problem.

Collaboration
[5.A.i]  Identify and justify necessary roles in a software development team.
[5.A.ii]  Recognize their own strengths, skills, and weaknesses, as well as those of others.
[5.A.iii]  Be able to network and see the value of others.
[5.B.i]  Understand the sources, hazards, and potential benefits of team conflict.
[5.B.ii]  Be able to teach and learn from peers.
[5.B.iii]  Be aware of and able to work through interpersonal conflict.

Communication
[3.A.i]  Identify and organize information in a format suited to the audience.
[3.A.iii]  Write clear, concise, and accurate technical documents following well-defined standards for format and for including appropriate tables, figures, and references.
[3.B.i]  Identify and organize information in a format suited to the audience.
[3.B.ii]  Plan interactions (e.g., virtual, face-to-face, shared documents) with others in which they are able to get their point across, and are also able to listen carefully and appreciate the points of others, even when they disagree, and are able to convey to others that they have heard.
[3.B.iii]  Produce effective verbal presentations.
[3.C.i]  Identify and organize information in a format suited to the audience.

Character
[4.A.ii]  Describe the strengths and weaknesses of relevant professional codes as expressions of professionalism and guides to decision-making.
[4.B.ii]  Recognize and evaluate potential impacts while making informed ethical and professional decisions.
[5.C.ii]  Accept responsibility for their own actions, and credit the actions of others.