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Exploring ABET Self-Studies: A Look at Pedagogy, Assessment, and Evaluation of Life-Long Learning

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Introduction

ABET's standards for accreditation encourage curriculum development in engineering based on the achievement of specific outcomes. Outcome-based curriculum design, however, presents engineering programs with two major challenges: placing limits on the "breadth" of each outcome; and clarifying the inherent vagueness in each outcome (or, defining the "specificity" of each outcome).[1] ABET intentionally writes their student outcomes with a degree of vagueness to avoid engineering programs from adopting prescriptive curricular design and to allow engineering programs to have flexibility and freedom of interpretation. However, this vagueness may confuse engineering programs about how to address each outcome effectively.[1] To address these types of issues, McGourty, Besterfield-Sacre, and Shuman called for operational descriptions of each outcome; although, they admitted that determining the specificity would be a challenge.[1]

Nichols and Nichols provided a step in the right direction to reduce this confusion; they recognized that intended student outcomes consist of cognitive, attitudinal, and behavioral elements that describe what students should be able to know, think, and do after the course of learning.[2] This breakdown helps programs identify the implicit components of an outcome. Based on our research, we revised these three elements and added curricular design elements organized into a two-dimensional analytical matrix. With this matrix, we posit that programs can more effectively interpret and implement student outcomes.

Still, programs may struggle with implementation unless they achieve consensus of interpretation for each outcome among their faculty. Without such consensus, a program cannot hope to integrate those outcomes across the curriculum.[1] Programs may be able to achieve this consensus more effectively for program-level outcomes when assisted by our proposed analytical matrix process applied to self-study reports—curriculum documents submitted to ABET for evaluation purposes. To illustrate this process, analysis of a single outcome would help to present the strategy that could be generally applied to any outcome.

If one specific outcome is to be chosen, however, then it should be chosen wisely. Student outcome (i) (referred to henceforth as "outcome (i)") is notoriously difficult, and is, therefore, a particularly interesting case to investigate. Outcome (i) calls for, "a recognition of the need for, and ability to engage in life-long learning."[3] Life-long learning has been considered an important element by ABET since the mid-1990s and researchers have expended sizeable effort to explore ways to foster and assess life-long learning.[4–10] However, a recent survey of ABET evaluators identified that outcome (i) was one of the most challenging outcomes for programs to measure in students.[11] Besterfield-Sacre et al. provided an explanation for why this may be the case: "One of the difficulties with developing measurable performance criteria for life-long learning is that there is no commonly accepted definition of what this concept means. Several authors have written about what it means to be a life-long learner, but little was found about what types of knowledge, skills or attitudinal sets are needed to become an effective 'life-long learner.'" (p.

105)[12] Thus, despite McGourty et al.'s call for operational clarification,[1] outcome (i) still appears to confound many engineering programs.

Our research was guided by the question, "How do engineering programs address ABET student outcomes as reported within their program self-study documents?" Our research goal was to help educators interpret the breadth and specificity of ABET student outcomes by offering a structural technique to interpret outcomes and to plan, implement, and evaluate curricula. This paper presents our research process—a curriculum design framework to map the components of student outcomes. To illustrate its effectiveness, we specifically chose the challenging outcome (i) as our case. This paper demonstrates one use of this technique by analyzing the aspects of outcome (i) that were present in a collection of engineering programs' ABET self-studies. This use of outcome (i) as an example should also help to minimize the confusion experienced by many programs regarding its possible interpretations and methods of assessment, pedagogy, and evaluation.

Background

ABET Accreditation and Self-Study Reports. ABET, formerly known as the Accreditation Board for Engineering and Technology, defines accreditation as "a review process to determine if educational programs meet defined standards of quality."[13] ABET, a not-for-profit and non-governmental organization comprised of several professional and technical societies, accredits engineering programs internationally and exists as the primary accrediting body for engineering programs in the United States.[14] For engineering programs to receive accreditation, ABET requires self-study reports that demonstrate their compliance with all applicable ABET criteria and policies.[3] Within a self-study report, specific criterion sections identify program educational objectives, the way the program prepares students to attain established student outcomes, the methods and procedures for continuous improvement, and the overarching program curriculum. Additionally, criterion sections outline administrative procedures, policies, and structures, such as faculty, facilities, and institutional support, which enable programs to achieve their educational missions.[3] Criterion 3, specifically, lists 11 student outcomes, designated (a)–(k), that ABET requires programs to address.

To address shortcomings associated with Criterion 3, the Engineering Accreditation Council (EAC) of ABET assembled a Criterion 3 task force in 2009.[10] The task force concluded that "some of the (a)–(k) components were interdependent, broad and vague in scope, or impossible to measure. As a consequence, program evaluators were inconsistent in their interpretation of how well programs were complying with Criterion 3."[15] As such, the EAC submitted a motion on October 15, 2015 to propose a set of changes to Criterion 3 and Criterion 5 (Curriculum). The proposed changes to Criterion 3 modifies and restructures the previous 11 outcomes (a)–(k) into seven new student outcomes (numbered as 1–7).[15]

Notably, the seven new outcomes omit the phrase "life-long learning." This motion represents a significant time of reflection in engineering education: a time when reform to accreditation requirements could dramatically change the way engineering is taught. Despite the potential removal of the phrase "life-long learning" from the prescribed outcomes, professional engineers will still need to possess the characteristics of a life-long learner to be effective. To this end, our findings demonstrate several components of life-long learning that are currently being captured by different engineering programs. Of these current components, only a small subset are included in the proposed changes. Our research will, therefore, provide a historical account of the life-long learning landscape that may be valuable for future comparative purposes. Further, while we used outcome (i) to conduct our research, the process and framework we present to interpret program requirements applies more broadly to general curriculum mapping and program design.

Curriculum design framework. For our research, we framed the self-study report as a planned curriculum document at the program level. The curriculum design framework provides a broad perspective of how student outcomes are being addressed.

Curriculum design principles call for the alignment between the curriculum elements of content, assessment, and pedagogy.[16–19] That is, effective curriculum design requires faculty to identify appropriate knowledge, skills, and attitudes as part of the content of the course (content), translate the course goals and content into specific learning outcomes that are measurable (assessment), and create meaningful, authentic learning activities for students to practice, gain feedback, and demonstrate the achievement of the learning outcomes (pedagogy). To achieve curricular alignment across the areas of content, assessment, and pedagogy, the planned goals of a course must be supported by meaningful activities for learning and must ensure that the intended learning outcomes are attained through appropriate assessment.

To adapt course design to program design, we modified the traditional curriculum framework by referring to the element of "content" as Description and adding the element of Evaluation. To understand how programs interpret student outcomes, it was more appropriate to frame our investigation around *Descriptions* of the outcomes, rather than sets of content-based objectives. For *Assessment*, we investigated how programs plan to measure individual student learning of outcomes. The element of *Pedagogy* related to the methods, tools, and techniques that programs employ to help students achieve the outcomes. We added *Evaluation* to capture how programs judge their overall ability to support student attainment of outcomes throughout their students' experiences. Based on this curriculum framework, we employed the operational questions shown in Table 1 to guide our research. For the purposes of this paper, the questions are phrased using the exemplar of outcome (i).

Table 1. Guiding operational framework for this study

Operational guiding question	Alignment with Curriculum Framework
How is outcome (i) described in the self-study?	Description
In what ways are programs determining students' achievement of outcome (i)?	Assessment
How are programs intending to satisfy the requirements of outcome (i)?	Pedagogy
How are programs measuring the success of their program in developing outcome (i) in students?	Evaluation

Methodology

The goal of our study was to analyze the planned curricula of engineering programs to determine how a sample of the engineering community addresses ABET outcome (i). We chose to focus on curricula at the planned level based on the assumption that these documents represent the high-level guiding direction from which engineering programs plan and implement their curriculum. These perspectives are conveyed throughout the self-studies that ABET requires programs to submit in order to be evaluated for accreditation. Therefore, ABET self-studies represented a valuable source of data to be used as artifacts for qualitative content analysis.

Data Collection. Because different engineering disciplines might possess unique interpretations and practices regarding each of the ABET outcomes, we grounded our study in mechanical engineering to focus on a single discipline's perspective. Future research may explore perspectives across other disciplines. As the discipline of mechanical engineering typically graduates nearly twice as many undergraduates as any other engineering discipline, we selected it as the most relevant discipline to investigate.[20–22] Additionally, because engineering programs reapply for accreditation every six years, and because accreditation procedures change over time, we limited our selection to studies that were submitted within a six-year window (2008–2014), or one evaluation cycle.

We collected self-studies in September 2015 using the Google search engine, www.google.com, with the search string "mechanical engineering ABET self-study." Our criteria for exclusion of self-studies were (1) those from non-mechanical engineering programs (also rejecting mechanical engineering technology, or MET, programs) and (2) those outside of the 2008–2014 timeframe. Our search concluded once we had reviewed 10 consecutive search pages without collecting any additional self-studies that met the inclusion criteria. This process led to the collection of nine mechanical engineering self-studies, including one from our own home institution, which was used for calibration purposes and not included in the final analysis.

We classified these self-studies using the basic classification of the Carnegie Classification of Institutions of Higher Education (see Table 2).[23] The distribution shown in Table 2 indicates that the perspectives we explored represent schools from a variety of sizes. We anonymized the schools selected for this study to avoid judgement of the reported interpretations and practices through lenses potentially biased by perceptions of program quality.

Data Analysis. The analyzed self-studies each consistently followed the format of the ABET template. Despite the consistent format, the actual data provided and the layout of that data varied from document to document. This variability prevented a truly streamlined process for collecting the information most relevant for answering our question.

To maximize reliability, both authors analyzed each self-study and discussed any discrepant interpretations. Individually, we open coded one self-study (our home institution's) and discussed results through multiple iterations to explore the general structure of the self-study document and to devise a practical, consistent scheme that captured the information needed to answer our research question. This process also served to calibrate our coding strategy.

Table 2. Distribution of included schools' Carnegie Classifications

Institution	Classification Status	Enrollment*
School A (not included in analysis)	Doctoral Universities: Highest Research Activity	40,000
School B	Doctoral Universities: Highest Research Activity	50,000
School C	Doctoral Universities: Highest Research Activity	26,000
School D	Doctoral Universities: Higher Research Activity	29,000
School E	Doctoral Universities: Higher Research Activity	16,000
School F	Doctoral Universities: Moderate Research Activity	11,000
School G	Master's Colleges & Universities: Larger Programs	17,000
School H	Special Focus Four-Year: Engineering Schools	3,000
School I	International University (Does not fit Carnegie System)	31,000

*Approximate enrollment data for Fall 2014, rounded to the nearest thousand.

Following this initial setup, we conducted full-text reviews of the self-study reports in which each author identified applicable text using the curriculum review framework. A two part coding scheme was used for organizationally tagging of the content, as well as identifying the nature of the content. The organizational tagging consisted of identification of the relevant curricular design elements.

The finalized coding scheme consisted of two parts: a set of organizational tags, which would allow for sorting with spreadsheet software; and a subsequent set of structured content codes. The first organizational tag indicated the corresponding curricular design element (D for description, A for assessment, P for pedagogy, or E for evaluation). The second organizational tag indicated the extent to which the identified text connected the content to outcome (i) (see Figure 1):

- If the self-study stated that a given practice directly addressed outcome (i), it was coded as "E" for explicit;
- if at some point in the self-study, the program tied one of its own program outcomes to outcome (i), and then suggested that a practice addressed that program outcome, it was coded as "C" for connected;

- or, if we, as the researchers, recognized that the self-study could or should have connected a practice to outcome (i) and either the self-study did not do so or it was unclear, it was coded as “P” for possible.

The last organizational tag designated the section of the self-study in which the coded content occurs. The content codes were structured based on the curricular design element identified and information contained, such as the technique that was used and on whom.

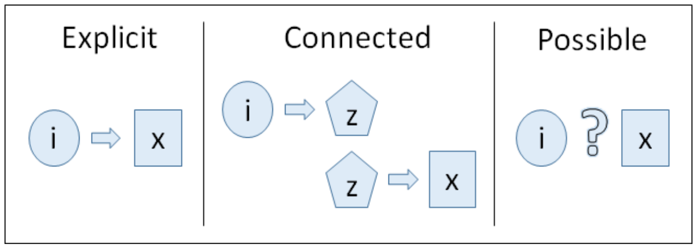

Figure 1. Illustration of “extent to which the self-study connected the content to outcome (i)” tag. If practice “x” directly relates to (i), practice “x” is coded as “explicit.” If outcome (i) is linked to program outcome or practice “z” and practice “x” is linked to practice “z,” practice “x” is coded as “connected.” If the connection between practice “x” and outcome (i) is not clearly stated but could or should be linked, practice “x” is coded as “possible.”

The coding scheme arrangement is exemplified in the following scenario. A self-study states in Criterion 4 that a survey was administered to graduating seniors asking the level of agreement with the statement, “I have participated in life-long learning activities during my undergrad coursework on campus.” This statement is used as a means of measuring program outcomes. The information was coded as follows: “E;C;4;Survey;Program;Graduating students;Participation in life-long learning activities in undergraduate coursework.” This code indicates the following about the specified practice: It was used as an *evaluative* measure (E); it measured a program outcome that was *connected* to outcome (i), (C); it is located in Criterion *4*; it used a *survey* as the measurement tool; it was administered by the *program*; it was taken by *graduating students*; and it used *participation in life-long learning activities* as the metric. The semicolons in the code function as delimiters for spreadsheet software.

Once all eight self-studies were reviewed and coded, we explored and synthesized the aggregated dataset to convey the entire landscape of outcome (i) based on our collection. While representing the landscape, we purposefully decided to exclude the level of connection (Figure 1) and the number of programs that addressed outcome (i) in any given way. Through this decision, we intend to avoid what might be interpreted as prescriptive advice for addressing outcome (i). This research does not aim to evaluate the procedures of any single school; rather, it is meant to provide a process for developing and implementing student outcomes. This research serves as a foundation for initiating discussion about accreditation procedures and ways to explore the characteristics of student outcomes establish meaningful assessment and evaluation across all outcomes. Insight into the situational context and boundaries of life-long learning, based on the intent of a subset of engineering programs, is merely an added bonus.

Exploring the landscape of outcome (i): Forming the larger map. The synthesis process consisted of two phases. In the first phase, all of the codes for each curricular design element were synthesized together to form a graphical representation of that curriculum element for outcome (i). For a given curriculum element, these representations showed comprehensive views of each portion of the content codes—including, for instance, the contexts, contents, and methods for pedagogical codes. Each representation, taken individually, portrays the landscape of that particular curricular design element derived from our set of mechanical engineering self-studies. Table 3 outlines the criteria we applied in order to classify the items coded within the self-studies according to curriculum elements of our DAPE framework.

Table 3. Explanation of curriculum elements

Curriculum Element	Explanation of self-study items in relation to curriculum element
Description	Items that describe or illustrate the program's interpretation of outcome (i).
Assessment	Items that indicate assessment of individual student learning or achievement of outcome (i).
Pedagogy	Items that indicate teaching practices or curricular/programmatic opportunities to develop or achieve outcome (i).
Evaluation	Items that indicate evaluation of the program's overall ability to develop or achieve outcome (i).

During the second phase, we performed additional analysis of each of the four curriculum element representations from the first phase of synthesis to integrate all the information into a larger, cohesive landscape that represents outcome (i). Through this process, we discovered common themes across the four elements and identified a dimensional structure to organize the operational variables, or components, associated with outcome (i).

Findings

In the following sections, we present our findings addressing the nature of our technique based on our DAPE curricular framework, using outcome (i) to illustrate the process. First, we consider the people and methods involved in assessment and evaluation. Second, we demonstrate how this process can identify operational dimensions and elements of student outcomes. While we were able to identify aspects of pedagogy employed by programs, the scope of pedagogical processes was limited. We suspect that a possible reason for this may be the nature of self-study documents as accreditation documents that constrain programs to include abridged course outlines rather than complete syllabi. Therefore, sources other than self-studies may be more suitable to investigate detailed pedagogical practices.

People and methods involved in assessment and evaluation. The people involved in the ABET self-studies are current students, graduating students, alumni, faculty, employers, and advisory board members. Each of these actors is a source of information for the assessment and evaluation of student outcomes. Table 4 presents a list of the type of methods used by programs to collect information for assessment and evaluation purposes identified for outcome (i).

Felder and Brent provided an extensive list of possible assessment tools at both the program- and course-level.[19] While our list combines some of the possible tools that Felder and Brent suggested, we noticed that a few tools were missing from the data we analyzed. Specifically, we did not encounter the following tools: self-analysis, learning logs, or journals; peer- or selfevaluations; student portfolios; behavioral observations, ethnographic, or verbal protocol analysis; research proposals or student-formulated problems; abstracts or executive summaries; letters or memos; or written critiques of documents or oral presentations. It is likely that we did not reach saturation through our relatively small sample and it is possible that programs may utilize these techniques. However, programs should consider employing a variety of means to assess and evaluate their students on each outcome to most effectively triangulate outcome measures.[19] Therefore, programs should consider a wider selection of these tools.

Dimensions of outcome (i): The Curriculum-Outcomes Matrix. We focus this paper's findings on the results of the second phase of synthesis, which explored the four curricular design elements collectively for outcome (i). While Nichols and Nichols suggested that student outcomes should be designed to include cognitive, attitudinal, and behavioral aspects,[2] our synthesis, interpretation, and integration of the items associated with outcome (i) seemed to be more appropriately described by the following three dimensions: Perceptions, Behaviors, and Abilities. The Perceptions dimension is characterized by the beliefs, values, and attitudes, associated with life-long learning, similar to Nichols and Nichols' attitudinal dimension. The Behaviors dimension, identical to Nichols and Nichols', is characterized by the specific practices and activities of a life-long learner. The final dimension, Abilities, differs most significantly from Nichols and Nichols' cognitive dimension. While the cognitive dimension consists specifically of knowledge, the components we found did not appear to coincide with knowledge, per se, but rather with the skills and experiences required for students to perform life-long learning effectively. This modification aligns with Jarosz and Busch-Vishniac's claim that outcome (i) does not relate to topical curriculum content.[24] These dimensions can also be seen in the wording of outcome (i) (see Figure 2).

Table 4. The methods used by programs for data collection on assessment and evaluation of outcome (i)

Method	Example
Survey	Course evaluations
Administrative program data	Administrative records of student participation in internships
Fundamentals of Engineering Exam	Success rate of students who passed F.E. exam.
Stakeholder Meetings	Faculty and administration meet with program advisory board.
Interviews	Faculty chair meets individually with senior students to discuss educational experience.
Course Related Data	Exams, quizzes, assignments, projects, presentations
Instructor Objective Evaluation	Course instructors complete self-assessment of the achievement of outcomes.

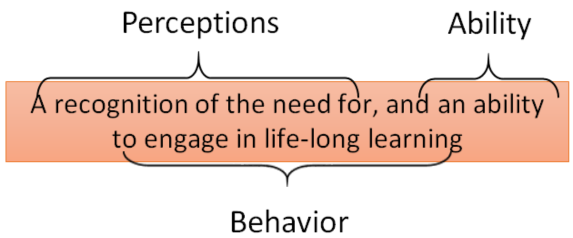

Figure 2. The mapping of Perceptions, Ability, and Behavior dimensions onto outcome (i)

We organized our findings into what we call the "Curriculum-Outcomes Matrix." This matrix (Figures 3–5) organizes the items identified throughout the self-studies into similar components (separated by the vertical dotted lines) that fit into each of the previously mentioned dimensions (Perceptions, Abilities, and Behaviors) across the four curriculum framework elements (Description, Assessment, Pedagogy, and Evaluation). Our DAPE classification indicates how the item was used in the self-study and the location within a given dimension demonstrates how well that item is aligned across the curriculum elements. For example, the "valuing honesty and life-long learning" item that appears in the Assessment row of Figure 3, is vertically organized with the Description of "commitment" and the Evaluation items of "willingness to work through challenges" and "commitment and belief." The item specifically means that programs were assessing student perceptions of valuing honesty as a measure of their learning.

It should be noted that the horizontal axis of Figures 3–5 does not represent a continuously changing quantity, but instead serves to organize the different interpretive components of outcome (i). Thus, there is no deeper meaning to the fact that the "commitment" component lies to the left of the "motivation" or "importance" components in Figure 3. In some cases, the arrangements were dictated by the fact that some items spanned more than one component. For instance, in Figure 5, we felt that assessing students' "technical conference attendance" related to the components of "participation in professional societies" and "professional development." Thus, horizontal placement of a component within a dimension does not indicate any kind of amount. However, we did believe that some practices, skills, or attitudes spanned across these three dimensions; for instance, the identity-related question of "feelings about ability" falls into both the Perceptions and the Abilities dimensions.

When used as a curriculum planning tool, the Curriculum-Outcomes Matrix offers two opportunities for analysis: looking *across* curriculum dimensions and looking *within* individual curriculum dimensions.

Items included within a curriculum element. Read horizontally, the matrix presents examples of how items within each curriculum element are used in self-studies. For example, while four elements of outcome (i) were identified as Descriptions of Perceptions (informational need, commitment, motivation, or importance) only two elements were identified as Assessment of Perception measures (valuing honesty and life-long learning, and awareness of role in engineering society). This structure allows educators and administrators to identify other items that may be part of the curriculum element and how it may be used to support students' learning and program improvement. It is also desirable for educators to generate more items that meet their own program needs to sufficiently express outcome (i). This process will support the

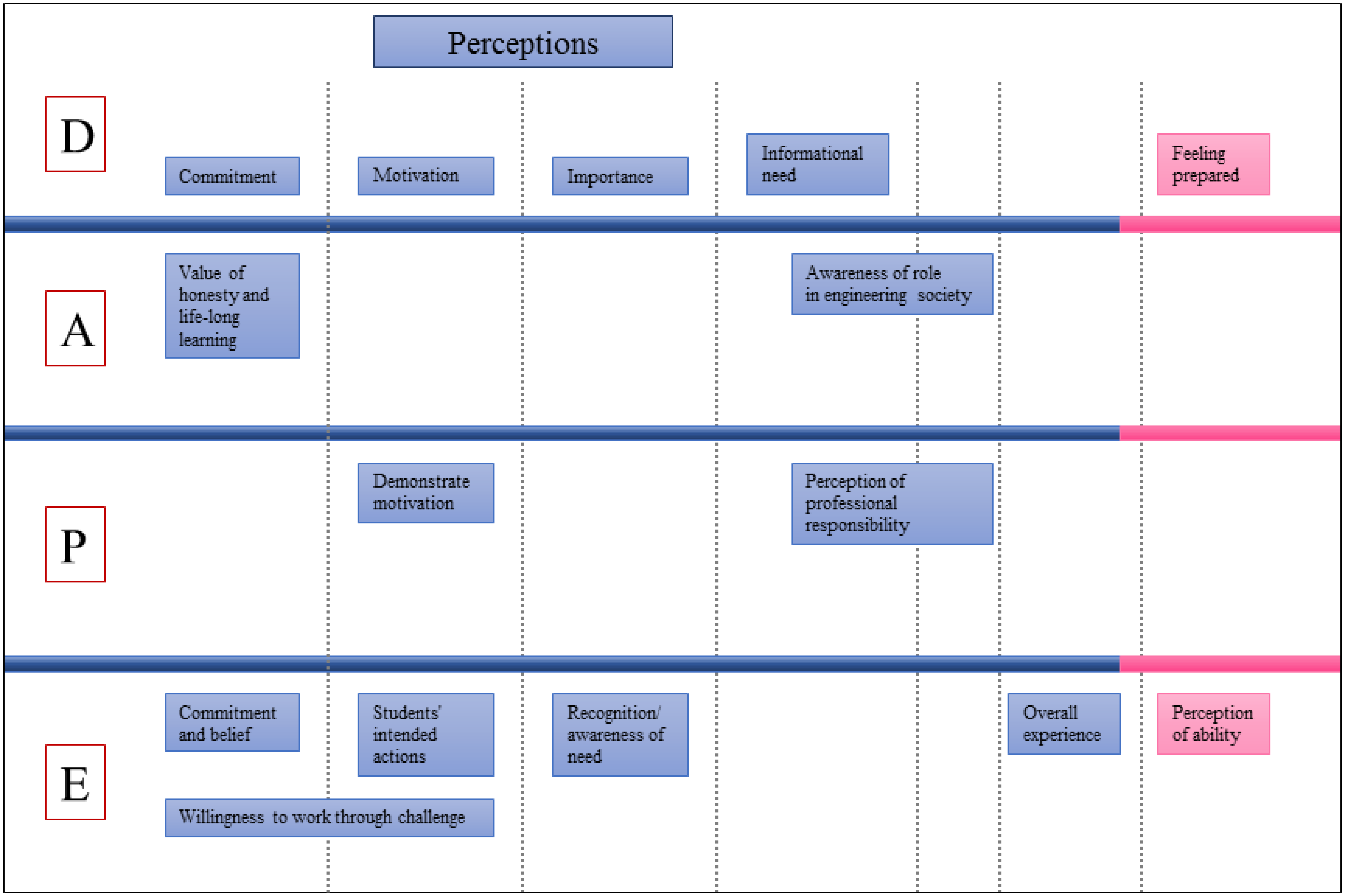

Figure 3. Curriculum-Outcomes Matrix of Perceptions of outcome (i)

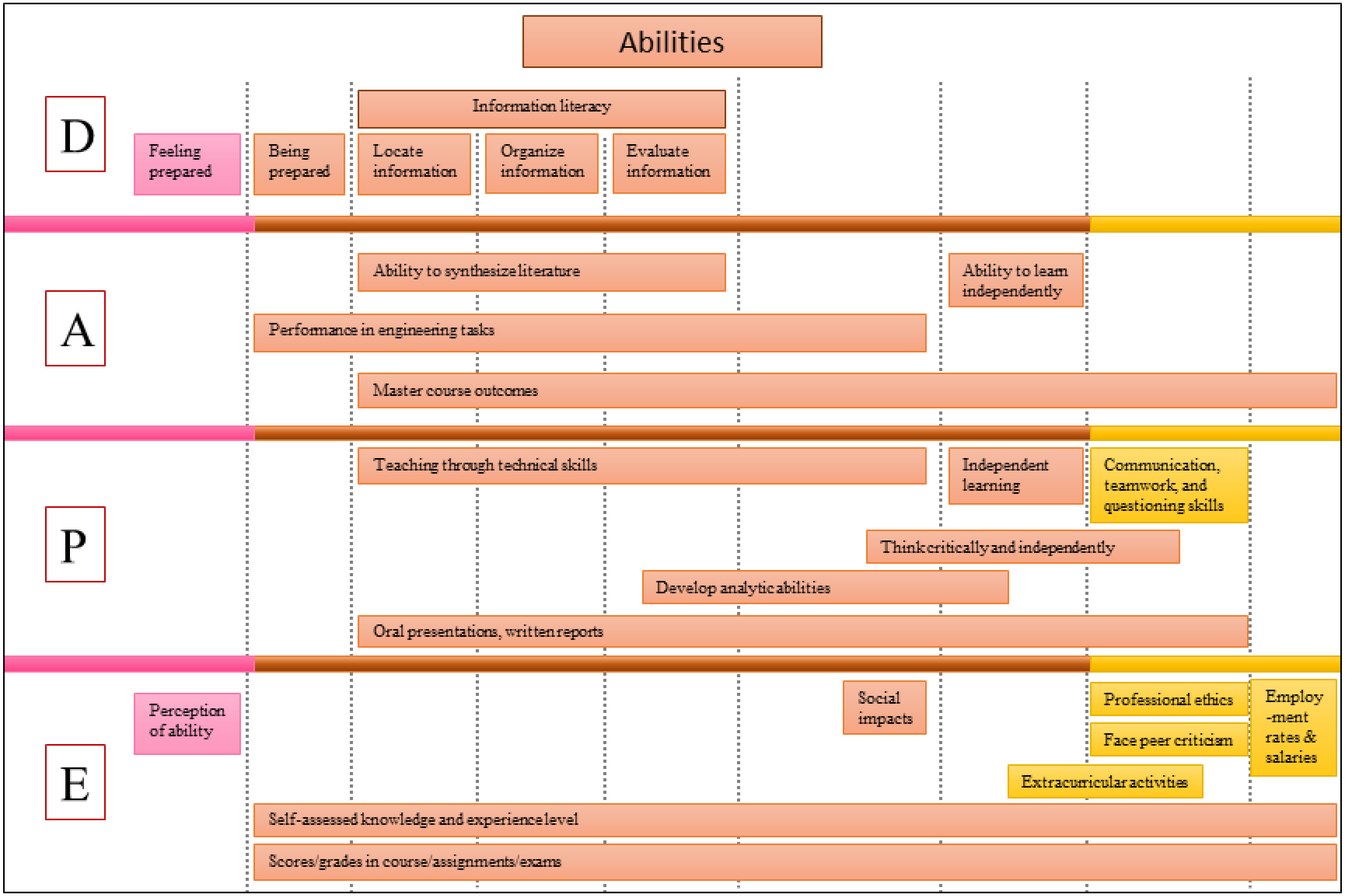

Figure 4. Curriculum-Outcomes Matrix of Abilities of outcome (i)

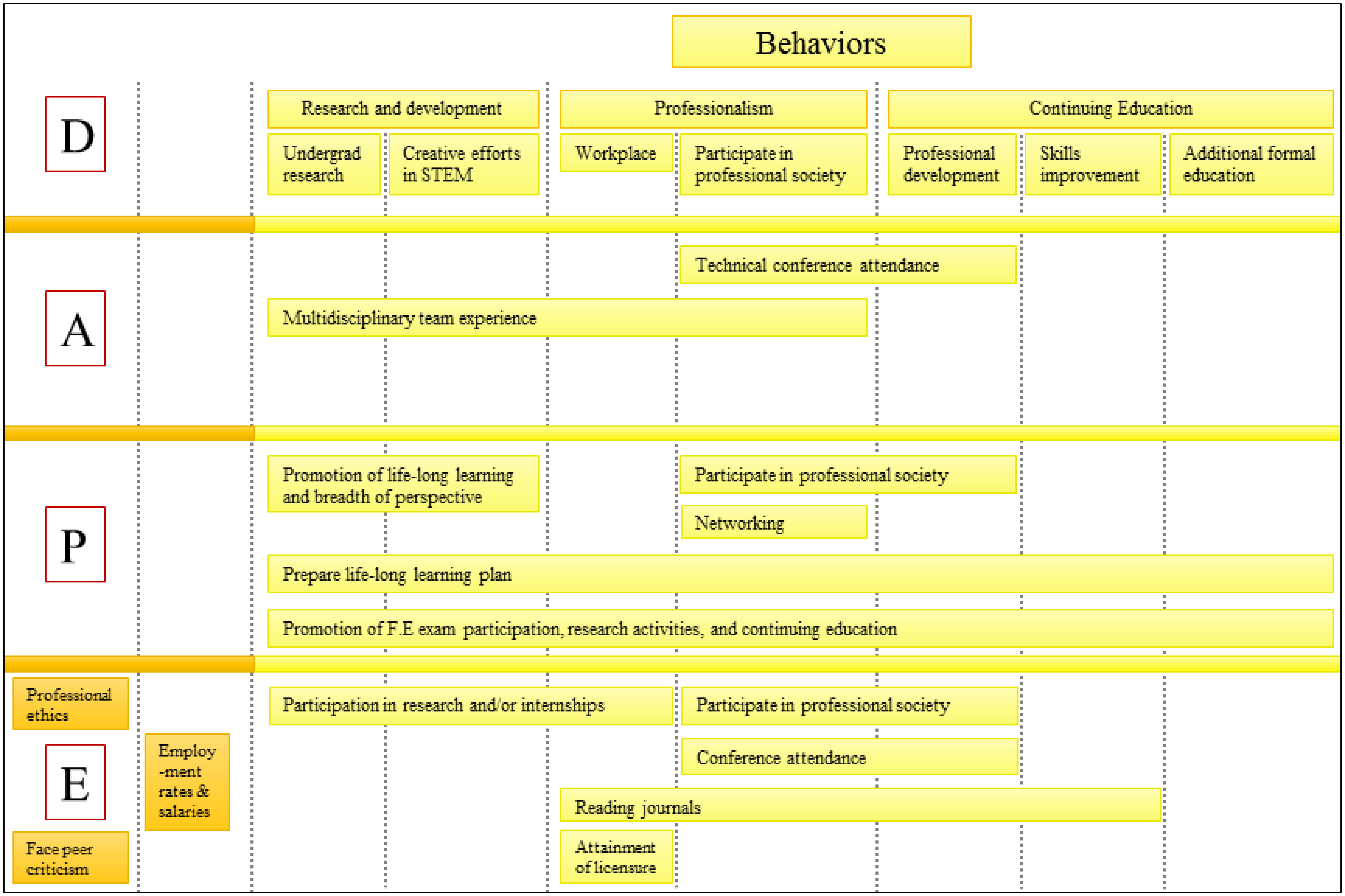

Figure 5. Curriculum-Outcomes Matrix of Behaviors of outcome (i)

development of a more detailed and aligned Curriculum-Outcomes matrix for individual program needs and for other student outcomes.

As three connected maps, the Perceptions, Abilities, and Behavior Dimensions of outcome (i) represent the multi-dimensional nature of outcome (i). Each map presents examples of items that constitute each dimension. We encourage educators to consider how other dimensions may exists for outcome (i) as a way to develop and specify elements for teaching and learning.

Alignment within curriculum element items. Read vertically across the columns, an analysis for curriculum alignment can be conducted by identifying where missing elements are located. For example, in Figure 3 for Perceptions, "motivation" is identified in the Description dimension. As we read down that column, it is clear that there exists ways that programs may be addressing the pedagogical teaching and program evaluation of motivation in the curricular dimensions of Pedagogy and Evaluation respectively. However, in the curriculum dimension of Assessment, an item is missing that targets the assessment of students' motivation.

Limitations. The findings within the matrices (Figures 3–5) are presented as an aggregate collection of items from all self-studies surveyed. Therefore, the presented matrices do not represent any single school, but serve as a way of thinking about the kind of elements that exists within each dimension. Also, we must emphasize again that the matrices do not indicate the number of schools that included a given item; this was a deliberate decision to avoid influencing programs to focus on any one component. Additionally, the Curriculum-Outcomes Matrix presents our interpretation of the items of outcome (i) and their use in program planning as observed from the program self-study reports. However, due to the small sample size of self-study reports, the extent of items presented for outcome (i) may be limited.

Another limitation was due to the nature of self-studies. Self-studies do not necessarily provide all the relevant information for determining the ways programs interpret, assess, or teach a student outcome. For example, not all self-studies included appendices with course syllabi that would allow us to see the specific details of how outcome (i) was intended to be addressed in the course. At the program level, self-study reports did not necessarily delve into the level of detail for curriculum implementation that we expected. Therefore, it was not possible to conclusively determine the way schools were framing outcome (i) based on our findings, nor was this the intention of our work.

Discussion

While we contextualized our findings through outcome (i), the broader applicability of our methods of analysis warrants further discussion. We propose three distinct ways to apply our methods of analysis and the Curriculum-Outcomes Matrix:

1. *analysis of outcomes to explore meaning and characteristics*
2. *curriculum planning to create high-quality learning opportunities, and*
3. *curriculum evaluation for continuous improvement.*

Our discussion of these purposes will be supported by specific implications related to outcome (i), highlighted by the mappings we presented in the findings section.

Analysis of outcomes to explore meaning and characteristics. As Besterfield-Sacre et al. identified, the challenge of defining effective outcomes lies in determining appropriate breadth and specificity of the outcome.[12] The breadth and specificity may be unique for individual programs as faculty and administrators determine the level of detail they deem most appropriate. Therefore, faculty and administrators are allowed the flexibility to explore the components of each outcome and what constitutes individual items in the Curriculum-Outcomes Matrix. Consequently, no single interpretation exists for any given outcome—a fact that may cause confusion in program development. To remedy this, the methods of analysis we have presented may be used by other researchers to map interpretations and implementations that have been employed by the larger engineering community for each outcome, which may illuminate previously unconsidered options. Additionally, an exploration of meaning and characteristics of outcomes can provide a historical record to show how engineering education may be changing over time.

Our analysis demonstrated 16 possible components (the columns in Figures 3–5) to include in the interpretation of outcome (i), some of which had multiple sub-components (Professionalism, for example). This leads to a list of reflective questions: Is this list comprehensive, or are there other aspects of life-long learning? How might additional components fit within the proposed dimensions of Perceptions, Abilities, and Behaviors? Is there an additional dimension beyond Perceptions, Abilities, and Behaviors? Are the methods in Assessment, Pedagogy, and Evaluation meaningful and reliable to support students' learning and to make decisions about a program's effectiveness? We encourage educators and administrators to have conversations about the items presented in Figures 3–5 and to interpret and develop their own items to meet the needs of their programs.

Curriculum planning to create high-quality learning opportunities. As a curriculum planning tool, the Curriculum-Outcomes Matrix offers an organizational structure with which programs may plan their curriculum to most effectively meet the needs of accreditation and their identified learning objectives. Program faculty and administrators can discuss what components they believe to be present within each outcome. While we suggest that each dimension (either Behaviors, Abilities, and Perceptions, or behavioral, cognitive, and attitudinal) contain multiple components to optimize triangulation of measurement, that decision remains at the discretion of each program. Regardless, this organization should encourage consideration of multiple options and should help ensure that all faculty and administrators achieve adequate consensus of interpretation.

Our findings indicated a number of opportunities and considerations for curriculum planning specifically pertaining to outcome (i). Within the proposed ABET changes to student outcomes, it would appear that the proposed outcome 6, stated as "an ability to recognize the ongoing need for additional knowledge and locate, evaluate, integrate, and apply this knowledge appropriately," attempts to capture some components of outcome (i). While this element of information literacy was identified in the Abilities dimension of our findings, this is only one aspect of how programs are currently addressing outcome (i). Our findings highlight the multiple ways programs are thinking about outcome (i) that likely add value to students' learning and development. We urge educators to think about how the proposed outcome 6 in its current articulation may be more appropriate as a course-level outcome that supports a broader program educational objective, as opposed to being identified as a program educational objective in itself.

In other words, while meaningful assessment and evaluation depends on the identification of specific and measurable learning outcomes, applying a narrow, course-level learning outcome at the program level presents the risk of eliminating important additional components of student learning that can derive from a more nuanced, encompassing program-level objective.

In the context of this research, we posit that it is more desirable for programs to use broad, overarching program educational objectives to develop finer detailed components. This process will allow educators to develop a richer understanding of what constitutes a student outcome for their program to articulate corresponding methods of pedagogy, assessment, and evaluation for that outcome. Despite the potential for omission of outcome (i) in the proposed changes to the ABET accreditation criteria, future ABET self-study reports will continue to require programs to describe how the outcomes are being developed in students and to provide evidence for success. Our Curriculum-Outcomes Matrix presented in this paper offers a structured way for programs to think about developing their program outcomes and present that information.

Curriculum evaluation for continuous improvement. We have framed our research as a way to survey the landscape of student outcomes and, within a curriculum framework, to identify boundaries around the components that might comprise that outcome. This approach serves as a systematic, quality assurance process to identify possible gaps in curriculum alignment. The importance of alignment cannot be understated in terms of the educational benefits for the students and overall effectiveness of the program, as is supported by curriculum design principles.[16–19]

As the Curriculum-Outcome Matrix for outcome (i) indicates, individual items are not consistently aligned across the four curricular elements, which may be of concern for program evaluators. Further, when interpreting the Curriculum-Outcome Matrix for outcome (i), it is important to note that the matrix represents an aggregate of data across multiple programs. Therefore, even the components that appear to exhibit alignment across all four curricular elements do not necessarily indicate alignment within any individual program. We encourage educators and administrators to use the structure of our maps to self-evaluate the alignment of their own programs across Description, Assessment, Pedagogy, and Evaluation.

The use and appropriateness of program evaluation data offers another opportunity for our Curriculum-Outcomes Matrix to be applied to curriculum evaluation. While programs may use data from the assessment of students' learning for program evaluation purposes, this research highlights the need for specific evaluation metrics that are aligned with the curriculum elements of content, assessment, and pedagogy. Meaningful program evaluation procedures will ensure feedback mechanisms for continuous program improvement. As such, we encourage educators and program administrators to be critical while they determine program evaluation metrics. For example, it was evident in the self-studies that programs view participation in undergraduate research experiences and professional internships as a positive outcome. However, it was unclear how programs measured the extent of contributions of these experiences on students' development of outcome (i). In another instance, survey questions distributed to graduating students and alumni asked participants to self-report their feelings of preparedness to engage in life-long learning. While self-reported measures may be valid when the results are aggregated and used to compare the performance of groups, we encourage educators and administrators to consider focused ways of measurement at the individual student level that will serve to support student learning and provide meaningful data for program evaluation.[2]

Additionally, the landscape offered in this paper included a survey of the people involved in assessment and evaluation and how programs are gathering information from these various stakeholders. Although we did not provide detailed data in the Findings section regarding the associations between those people, the collection techniques, and the data collected by each, we had several instances throughout our analysis of the self-study documents in which we questioned whether those three items were adequately aligned. We recommend that program administrators critically evaluate their data collection practices in terms of whose perspectives are most relevant for measuring specific metrics and what tools are most appropriate for collecting those measurements.

Conclusion

This research explores the ways engineering programs address student outcomes in their ABET self-study reports using outcome (i) as an applied case. We have presented the Curriculum-Outcomes Matrix to organize the observed elements of outcome (i) across three outcome dimensions of Perceptions, Abilities, and Behaviors. We also classified the items within each dimension using a curriculum framework of Description, Assessment, Pedagogy, and Evaluation, to identify the curricular relevance of each item. With this classification tool, educators and administrators are encouraged to find ways to further develop and interpret the components of student outcomes and to identify additional elements that may be added to support student learning. The Curriculum-Outcomes Matrix also illustrates how curriculum design principles may be broadly applied to curriculum design at the program level. In this way, administrators may self-evaluate their own program for curriculum alignment and identify where gaps may exist across their interpretations, pedagogy, assessment, and evaluation.

Our view of the landscape of outcome (i) illustrates what may be planned for engineering curricula. Further research into the enacted practices performed by educators and administrators, as well as the student experience of teaching and assessment of outcome (i), would provide valuable insight for programs to develop their curriculum. This information also demonstrates the differences between the possible interpretations of the previous student outcomes and the proposed student outcomes. Through this work, we hope readers may become more sensitized to accreditation procedures, assessment and evaluation practices, and how curriculum design may be conducted at the program level.

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