MATCHING ASSESSMENT METHODS TO OUTCOMES: DEFINITIONS AND RESEARCH QUESTIONS[*]

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Abstract

The "EC-2000" accreditation criteria require engineering programs to develop and implement systems for continuous improvement. Faculty must demonstrate that the outcomes important to the mission of the institution and the objectives of the program are being met via sound assessments, and must provide evidence that these results are applied to the further development and improvement of the program. Consequently, outcome assessment and continuous curriculum improvement now have come to the forefront of engineering education. In particular, EC-2000 asks engineering educators to assess the educational processes and at least eleven outcomes within their institutions. This is forcing faculty to both examine methodologies that have been successfully applied elsewhere and to begin to develop new methodologies or extend existing approaches where necessary. We are conducting an extensive research project directed at better understanding and characterizing both the outcomes and the methodologies that are available for use is assessing undergraduate engineering programs. In this paper we provide an overview of many of those methodologies and discuss research questions that are currently outstanding.

I. Background

In the early 1990's, the first of a series of reports emerged that recognized the serious deficiencies in engineering education and called for major reforms. The American Society for Engineering Education's *Engineering Education for A Changing World* proclaimed that "engineering education programs must not only teach the fundamentals of engineering theory, experimentation, and practice, but be relevant, attractive and connected," preparing students for a broad range

of careers and lifelong learning [1]. Today's education must provide the "technical knowledge and capabilities, flexibility and an understanding of the societal context of engineering." The National Science Foundation's complementary report, *Restructuring Engineering Education: A Focus on Change,* stressed similar themes [2]. It recommended that laboratory and internship experiences provide broader contexts where students would view trade-offs in the design, development and implementation of engineering systems. Engineering education would become flexible enough to support diverse career aspirations and engineering courses would include a broad range of concerns: environmental, political and social issues; international and historical contexts; and legal and ethical ramifications. The National Research Council's Board of Engineering Education also recommended a number of actions for curriculum reform "including early exposure to 'real' engineering and more extensive exposure to interdisciplinary, hands-on, industrial practice aspects, team work, systems thinking and creative design" [3]. Three leading educators, Bordogna, Fromm, and Ernst, called for educators to "create an intellectual environment where students can develop an awareness of the impact of emerging technologies, an appreciation of engineering as an integral process of societal change, and an acceptance of responsibility for civilization's progress." [4]

In response to this call to revitalize engineering education, the NSF created the Undergraduate Engineering Education Coalition Program, a bold initiative aimed at "revolutionizing" education [5]. In all, eight coalitions involving nearly sixty schools were funded. Collectively, they produced a large quantity of curricula innovations, many of which are discussed in the recent proceedings of the ASEE national meetings and Frontiers in Education Conferences [6]. In addition, the NSF's Division of Undergraduate Education has funded a series of Curriculum and Course Development projects, many of which were targeted towards improving engineering education. Most recently, the NSF has funded two rounds of "Action Agenda" projects aimed at implementing and expanding upon many of these innovations.

Concomitantly, a group of leading engineering deans and educators, realizing that the current ABET accreditation criteria were stifling innovation, began the process that in 1995 led to EC-2000. To a large extent the collective recommendations have been incorporated into the new criteria, creating the current need for outcome assessment methodologies. With its list of eleven required outcomes, EC-2000 changed the accreditation focus from "what are you [the program] doing?" to "what are your students doing?" [7] A major requirement is the implementation of a "continuous improvement" system that enables these outcomes to be measured, evaluated, and the results fed back to the faculty in order for them to improve their educational processes. As a result, EC-2000 is causing the engineering education community to seek methodologies for ongoing assessment specific to each program's objectives.

A first consequence of EC-2000 was the Joint Task Force on Engineering Education Assessment's "White Paper" that called for the development of multiple assessment tools to assist in evaluating engineering program quality [8]. Two years after that paper's release, a series of assessment efforts began to emerge [9].

Several major conferences on engineering assessment have highlighted the need for methodologies. The first, *Best Assessment Processes in Engineering Education* [10] held at Rose-Hulman Institute of Technology in April, 1997 was chaired by three of the principals of this project

(Rogers, Olds and Miller. Highly successful, a follow-up "Best Practices" conference was held at RHIT in October 1998, and a third was held at RHIT in April 2000. In September 1997, a well-attended National Conference on Outcomes Assessment focused on the state of this important area [11]. It demonstrated that engineering educators could learn much from those who have applied assessment methodologies to other areas [12].

At the first *Best Assessment Processes in Engineering Education* (sponsored by NSF, ABET, Rose-Hulman Institute of Technology, and the Foundation and Gateway Coalitions) [13], the number of evolving approaches for evaluating engineering programs, as well as methodologies for measuring various student outcomes were apparent. Yet, two troublesome issues surfaced. Most proposed "assessment" methods had not been fully evaluated; indeed, many had yet to be implemented. Second, engineering administrators in attendance voiced concern as how to organize, implement and maintain an effective assessment program, given the severe constraints of time, manpower, and budget.

In addition, if there is to be a true "continuous improvement system," then relevant outcome information must be fed back to faculty in a timely manner. Not surprisingly, the existence of such feedback loops were concerns at both WPI and the University of Arkansas, the first two engineering programs evaluated under EC-2000 [14, 15]. These concerns have been repeated as additional programs underwent the pilot EC-2000 reviews and the first set of full-scale evaluations were performed. To date, approximately 60 engineering programs have undergone EC-2000 review. Those who have not are now seriously considering it as the optional period comes to an end.

To create proper feedback loops, we believe that it is necessary to delineate the processes within the engineering education system and better understand how faculty may control important aspects of those processes. We propose that such processes may include critical or core processes (e.g., curriculum, culture and class learning), as well as secondary processes (e.g., mentoring and advising. financial aid, etc. that support the core processes. The demographic descriptors that could be used to define student populations include such factors as SAT scores, class rank, geographic location, quality of high school attended, level of scholarship/financial aid, admission status (e.g., direct admit, transfer, probation) ethnicity and gender should also be examined. Other inputs may include financial resources of the institution, facilities, and support from state and local government as well as from private sources. Aldridge [16] and Besterfield-Sacre [17] among others have proposed models that relate the processes that make up the system to its outcomes

By modeling the system and providing the necessary feedback loops, we can better interpret the results we obtain with our various assessment methodologies. Modeling will enable us to better utilize the outcome measurements we obtain for decision making. Educational feedback models can be conceptual in nature, providing a framework for decision making, or they can be empirical. Researchers at the University of Pittsburgh have developed and implemented both types of models. These models have enabled faculty and administrators to identify those students most likely to leave an engineering program during their freshman year [18]; determine the impact of co-op and internships on the educational process [19]; and develop quality control charts for tracking student attitudinal changes [20].

II. Assessment Methodologies and Instruments for Outcome Measurement

We believe that there are a number of methodologies that have been used successfully in other areas with potential for assessing engineering education outcomes [21-27]. There is also a growing number of national assessment "repositories"; e.g., NISE resources [28], National Center for Higher Education Management Systems [29], AAHE [30], ASEE [31], NEEDHA [32]. Hence, there is no need to "re-invent the wheel." Rather, we need to transform what has been invented into a format that engineering faculty can readily use with confidence, since many of our institutions do not have the resources to do this on their own. Table 1 contains a list of potential assessment methodologies and potentially applicable outcomes. The purpose of this paper is to review these methods and provide some insight into what they are and where potential avenues for application and research exist.

Table 1: Assessment Methodologies and Outcome Measures

Outcome Measure	Physical Portfolios	Electronic Portfolios	Student Surveys	Alumni Surveys	Student Interviews	Focus Groups	Competency Measurement	Student Journals	Concept Maps	Verbal Protocols	Intellectual Development	Authentic Assessment
Apply math, science, and engineering	✔	✔	✔	✔	✔		✔		✔	✔		✔
Design/conduct experiments	✔	✔	✔	✔	✔		✔		✔	✔	✔	✔
Design component or system	✔	✔	✔	✔	✔		✔		✔	✔		✔
Function on multi-disciplinary teams		✔	✔	✔	✔	✔	✔	✔				✔
Identify, formulate and solve problems		✔	✔	✔	✔		✔			✔	✔	✔
Understand professional, ethical responsibility		✔	✔	✔	✔	✔	✔	✔		✔		✔
Ability to communicate effectively	✔	✔	✔	✔	✔	✔	✔	✔			✔	
Engineering in a global and societal context	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Recognize need for life long learning	✔	✔	✔	✔	✔	✔	✔	✔				
Knowledge of contemporary issues	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Use modern engineering tools	✔	✔	✔	✔	✔		✔					
Ability to integrate knowledge	✔	✔	✔	✔	✔			✔	✔	✔		
Positive attitude about Engineering		✔	✔	✔	✔	✔		✔		✔		✔
Student satisfaction with education	✔	✔	✔	✔	✔	✔		✔		✔		✔

III. Assessment Methodologies and Potential Research Questions

We believe that engineering educators interested in assessment should first direct their attention at adapting proven methodologies from other areas. New methodologies and instruments should only be developed where needed and where obvious voids are found. Table 1 lists some of these methodologies that have been developed elsewhere and suggests how they can be applied to the eleven EC-2000 outcomes in addition to three we have added – ability to integrate knowledge, positive attitude and student satisfaction. Below we describe each methodology and provide some insight into the research needed to improve upon it.

Physical portfolios are a collection of student work, usually gathered over time. The material collected is determined by what student outcomes are being assessed — for example, writing samples are collected to assess student writing, while project reports, team meeting minutes, student notebooks, etc. are collected to assess students' design knowledge and skills. However, a single, well-chosen portfolio entry can be used for multiple measures. The student or instructor can make decisions about what materials are included in a portfolio; materials may be from one course, a series of courses, or the entire curriculum. Often, students are asked to include a self-reflection piece in the portfolio to help them view their own growth and areas where improvement is needed. Portfolios can be used for both formative and summative feedback. All these features of a portfolio make it a strong candidate for outcomes assessment, particularly with respect to EC-2000 outcomes design, communications, and contemporary issues [33-37].

Research Questions: Portfolios are an excellent triangulation device — a qualitative way of validating such quantitative measures as transcript evaluation and student attitudinal surveys. We need to develop rubrics for portfolios that will allow them to be used for cross-institutional assessment. We also need to explore ways in which electronic and other types of portfolios can be used more efficiently than traditional portfolios, which are generally time-consuming to maintain and evaluate.

Electronic portfolios (*eportfolio*) are a method that allows students to submit evidence of their progress toward achieving learning outcomes in an electronic format. For each student, outcome goals are defined with specific performance criteria. Students must evaluate evidence from their collegiate experience and make decisions about how it relates to the performance criteria. Students must write brief reflective statements as to how the evidence relates to specific criterion (a). The evidence may be course-based, co-curricular, or from other experiences within the collegiate experience (e.g., co-ops, internships). Teams of faculty evaluate the evidence using rubrics to rate the level of competence the student has achieved. This information will be used to make decisions about the academic program. As this process is being developed at Rose-Hulman, the student is responsible for submitting evidence to his/her own *eportfolio*. The *eportfolio* has a web interface with a secure site for each student. It has an electronic database structure that supports a variety of electronic formats (standard software packages, html, pdf, digitized video, audio, etc.) The electronic database will enable faculty assessors to search across multiple files and extract data for assessment. The Rose-Hulman model minimizes the work that faculty do in the data collection process and puts the emphasis on faculty as the ones who are responsible to evaluate the students' work in regards to specific, focused criteria.

Research Questions: What are the implementation costs of an *eportfolio* system? What is the educational value for students? How can you get students to participate in the project? What criteria should be used to sample student work? What is the ease of the use *of eportfolios* for faculty assessors? How is assessment data transformed into information that can be used to improve the engineering program? How can a cost/benefit metric be established as a measure of the *eportfolio* project effectiveness?

Closed-form Questionnaires - Attitudinal Surveys are a practical method for evaluating student or alumni attitudes about engineering, aspects of their education, and their self-assessed abilities and competencies. Closed-form questionnaires are less costly to develop, administer and analyze than other types of assessment methodologies, particularly if a large data set is being collected and if statistically reliable conclusions are desired. By limiting the response choices, data collection can be repeated overtime. Thus, we can examine how attitudes are affected by particular interventions, change over time, or vary among groups of individuals. Like other methods described, a good closed-form questionnaire design requires considerable knowledge and skill if results are to be valid. We have developed closed-form questionnaires at both the student and post-graduation level. At the student level we have measured attitudes freshman have about engineering and their self-assessed abilities and observed how these measures change as a result of their educational experiences [38-40]. To date, this instrument has been adopted by eleven engineering programs, and is being examined by 20 others. Further, sophomore, junior and graduating senior assessment instruments have been developed to complement the existing freshmen instruments. We also have developed and implemented a closed-form questionnaire to assess engineering alumni/ae attitudes about the outcomes of their education. This latter survey reflects the EC-2000 criteria, while capturing information about the processes that an individual experienced as an undergraduate student [41-42].

Research Questions: We need to extend current assessment research by using questionnaires to track students' attitudes and competencies at a number of points in the educational process. These should extend from when they enter the engineering education system, at graduation, and as professionals, and address issues germane to EC-2000 and the educational processes they are/have experienced. Questionnaires that can be used across engineering disciplines and institutions should be developed and tested. Because self-assessed ratings are surrogates to true measures of students' competencies, the results from such assessments need to be anchored to outcome measures that consider performance and achievement of specific objectives.

Open-ended Surveys and Structured Student Interviews are used to elicit in-depth information about a particular subject, especially when the subject of concern is complex, and there are a number of avenues to explore [43]. Because of their one-on-one nature, open-ended surveys and interviews allow the subject to present his/her attitudes in a more private and less restricted setting than other methodologies, such as focus groups and closed-form questionnaires. This permits in-depth information to be obtained about potentially sensitive subjects; e.g., reasons for leaving engineering, one's position about ethical responsibility in school and as a professional engineer, one's definition and desire towards life long learning.

Research Questions: In terms of EC-2000, little research has been conducted in the area of assessment of professional and ethical issues in undergraduate engineering education and how stu-

dents acquire an understanding of the role engineering has in a societal and international context. Open-ended surveys and student interviews can be employed together with focus groups (described below) to investigate specific issues and to develop protocols and instruments aimed at assessing particular learning outcomes.

Focus Groups are used to identify the attitudes and perceptions that a group of individuals has relative to a particular subject or concept. They are commonly used when one is looking for exploratory or exhaustive information about a particular issue [43]. In an educational setting, they may be employed to probe student perceptions or determine if there are communication gaps between different subject groups, such as faculty and students. Focus groups have several advantages as an assessment method. First, by providing an environment in which the subjects discuss a particular issue, they facilitate the capture of 'real-life' data. Second, the dynamics of a group allow for particular issues to be explored in-depth, something that is not always possible with structured questions [44]. For example, a single individual may not fully understanding how engineering fits in a global and societal context, but collectively students may provide full knowledge and understanding of this issue given their diverse backgrounds and perspectives. If conducted properly, results of a focus group have high face and construct validity [45, 46].

Research Questions: Focus groups can be used in concert with open-ended surveys and interviews to investigate and assess the outcomes associated with professional and ethical responsibility, societal and global contexts of engineering, life long learning, teamwork, as well as attitudes about engineering.

Competency Measurement - competency-based surveying provides faculty and students with a means for quantifying performance with respect to specified knowledge, skills, and abilities. This type of assessment method is quite flexible and can be constructed for faculty-student rating and/or student-student (peer) rating. Competency surveys can also serve as a structure for self-assessment. One approach that has been successfully used in the classroom is a behavior-oriented computerized survey called the Team Developer™ [47]. Team Developer™ is designed to provide each student with developmental feedback regarding his or her effectiveness on several specific cognitive and behavioral skills [48, 49]. Applying multi-source assessment techniques, student team members rate both themselves and their teammates on items designed to identify skills that have been found to be important for practicing engineers. Each student receives a developmental feedback report that presents his or her "self" and team ratings on each survey item and highlights overall strengths and areas for development. Gaps between self-perceptions and the perceptions of others are clearly shown. Specific suggestions for development, keyed to the behavioral areas, are provided to assist team members in developing action plans based on their personal feedback.

Research Questions: One of the biggest challenges many faculty face when attempting to implement competency-based surveys is finding the time to collect, tabulate and then disseminate information. A computerized format like Team Developer™ helps to eliminate many of these obstacles. Using a computerized survey means that data can be collected and analyzed quickly and feedback can be provided quickly. This also means that more time can be spent reviewing information and ensuring that the feedback process is a meaningful one for students and instructors. The efficacy and validity of computerized survey processes must be further explored. Is-

sues to address include resource availability, ease of administration, longitudinal tracking of student performance, and confidentiality.

Student Journals are an established learning and assessment tool in college literature and writing courses and are becoming more widely used in other settings. The rationale for using journals is simple and pedagogically grounded — students learn better when given an opportunity to articulate connections between new ideas and knowledge they already possess. Journals are also an effective, non-threatening mechanism for creating a rich dialogue between student and instructor. Although primarily used as a formative assessment tool, journals can also be used for more formalized summative assessment of what students have learned and the knowledge they have constructed. For assessment purposes, journal writing assignments might include: 1) asking students to pose clarification questions on confusing or unclear topics and then attempt to answer the questions themselves; 2) asking students to apply the classroom analysis of a topic to everyday phenomena they observe; or 3) asking students to describe their thought processes for solving a problem, particularly open-ended, related to the course material [50-52].

Research Questions: Journals provide a rich and varied source of information about student learning processes and the ability to construct knowledge. However, we need to develop and pilot rubrics that will guide the use of journal entries for formative and summative assessment purposes. For example, how can student journals from one course or a series of courses be used to provide information about student or EC-2000 outcomes? How can a large number of journal entries be rapidly screened to collect valid assessment data?

Concept Maps are a graphical assessment tool used to evaluate cognitive structure in students by allowing them to visually describe relationships among concepts and topics in a course, series of courses, or entire curriculum. As such, concept maps may be used to probe for understanding and misconceptions as students internally structure their knowledge in a field of learning. Although originally used primarily as a classroom assessment technique, concept maps currently are being formalized as an assessment and evaluation tool. For example, maps can be used to provide information about students' ability to integrate knowledge from different parts of their curriculum and therefore can be used to assess such EC-2000 criteria as the students apply knowledge of math, science and engineering, and the ability to formulate and solve engineering problems [53-55].

Research Questions: Since concept maps involve visual representation of connections among concepts, they are inherently difficult to assess and score reliably. We need to formalize the use of concept maps by developing guidelines and rubrics for administering and scoring concept maps for various purposes (classroom assessment, individual student feedback, curriculum assessment and evaluation).

Verbal Protocol Analysis (VPA) is a research method that requires subjects to "think aloud" as they perform a task [56]. It is a particularly valuable for collecting data about the processes that students use as they solve problems. Once the verbal protocols are collected via audio and video tape, they are transcribed; segmented into codable units of subject statements; coded according to a pre-defined coding scheme; and analyzed to answer specific research questions. Of the eleven EC-2000 outcomes, at least five are purely process skills while most of the others contain some

process.components. Verbal protocol analysis is a powerful tool that can be used to understand some of the process outcomes such as the "ability to design a system, component, or process". Atman has used this research method to assess engineering student learning of the design process and has documented differences in student design processes in three cases: 1) after completing an undergraduate engineering degree, 2) after the first semester freshman year, and 3) after the short term intervention of reading a text book [57-64].

Research Questions: Verbal protocol analysis is a very time consuming analysis technique that is used most frequently as a research tool. However, this type of process data is invaluable in the level of detail it can provide to guide curriculum changes. Methods to obtain relevant information in a timely manner need to be developed and validated. For example, can we identify key design process variables that correlate with design quality? Can we then develop specific design problems that will allow us to easily observe these behaviors? Are there analysis methodologies that yield assessment information with less effort than a full verbal protocol study?

Intellectual Development - Students are expected to develop intellectually in addition to acquiring knowledge and skills in a specific engineering discipline. Several ABET outcome criteria imply that students are able to think critically about their work and have developed higher order thinking skills (analysis, synthesis, evaluation as defined by Bloom) [65-67]. These include the ability to conduct experiments and analyze and interpret results, to design, formulate, and solve engineering problems, and to understand engineering in a global and societal context.

Research Questions: Traditional measures of intellectual development include pencil-and-paper questionnaires that have failed to demonstrate sufficient reliability and validity or expensive, time-consuming student interviews by certified experts. Can we develop computer software based on neural net and expert system technology to emulate the interview process?

Authentic assessment and performance-based assessment methods attempt to measure how well engineering students can apply acquired classroom knowledge and skills to more realistic problems approximating "real-world" engineering practice. Examples of authentic assessments include design projects, open-ended problems and lab exercises, simulations, and portfolios of student work. The key to authentic assessment is to create a context in which the student can individually or collaboratively demonstrate an ability to apply a well-developed problem-solving strategy. This might involve problem definition, gathering relevant information, generating solution alternatives, choosing the optimum solution given implicit and explicit constraints, assessing and improving the proposed solution, and effectively reporting the results of his/her work. Authentic tasks can be used for both formative and summative assessment, and ideally can be included as part of the student's assigned coursework [68-71].

Research Questions: As with other "non-test" assessment methods, authentic assessment has the advantage of providing rich data on student performance, but at the expense of increased time requirements to collect and analyze large amounts of descriptive data and observations. Development of well-designed scoring rubrics and methods for ensuring inter-rater reliability are required to make authentic assessment easier to use by engineering faculty and a viable assessment tool for ABET program evaluation. Guidelines also need to be developed which help faculty choose tasks that are good candidates for collecting authentic assessment data in engineering courses.

Modeling the Engineering Education System, specifically empirical modeling, is commonly used to draw correlated inferences and define relationships among different factors. Knowledge and insights about the relationships among the inputs, process elements, and outcomes of a system are useful, not only as an evaluation tool for better understanding the system, but also in targeting feedback of those factors most correlated with outcome. Empirically derived models may also be used to predict system outputs given information about the inputs and processes. To date, many of the empirical modeling applications in engineering education have focused on retention or performance [72-78]. Factors used in developing these models have included, but are not limited to: gender, race, geographical backgrounds, personality differences, attitudes about engineering, self-assessed confidence, as well as intellectual factors. Besterfield-Sacre, Atman and Shuman, we have developed regression models to predict attrition and performance in our freshman engineering program using quantified measures of student attitudes [79]. Implementation of these models has allowed freshman advisors to better inform students of opportunities that engineering offers, devise programs of study that take advantage of students' varied interests, and set realistic retention goals.

Research Questions: Modeling aspects of the engineering education system has the advantage of helping us quantify, define, and evaluate relationships among aspects of the student, their educational experiences (in particular, innovative interventions), and the outcomes of their education. We have conducted some promising preliminary research in this area using attitude questionnaires from engineering alumni [80]. Using a combination of different empirical modeling techniques (e.g. regression analysis, discriminant analysis, neural networks) coupled with the combined databases from this research, may be used to expand this pilot work.

IV. Future Directions – Investigating a Subset of Issues

Clearly EC 2000 has created a need for valid assessment methodologies that can be applied to engineering education programs across a broad spectrum of settings. Further, as discussed above, there is a relatively large array of assessment methodologies that should be applicable to engineering, many of which have been developed and successfully applied in other settings. However, before one can even start to apply one or more of these assessment methodologies to one or more of the eleven EC-2000 outcomes ("3a-k"**)**, several major challenges must be addressed.

One challenge that every engineering program faces involves achieving faculty consensus on the meaning and translation of the outcomes. A second, closely related task is to convert the desired outcomes into useful metrics for assessment. ABET was vague when it formulated the outcomes. The intent was to encourage individual programs to distinguish themselves by the way they defined their engineering education. Although this has provided engineering faculty with flexibility and the opportunity to meet "customers' needs," the task of outcome definition has proven to be both substantive and often overwhelming. Further, the context in which each outcome is used impacts its definition. As part of our research, we have taken a first step by closely examining each of the EC-2000 outcomes and giving each a high level of specificity.

In an effort to provide order and direction to this critical initial step, we have thoroughly researched each outcome and proposed a framework that divides each outcome into a comprehensive, ordered set of attributes. Engineering educators may use this framework to select attributes from each outcome that are suitable for their curricular needs. Two papers in the Special Issue of the IEEE Transactions on Engineering Education describe the framework and the process used to create it, and give specific examples of how it can be applied [81, 82]. Hence we have presented engineering educators with a "buffet of attributes" from which they can pick and choose and directly use in the measurement of their courses or programs can be found at our web-site:

www.engrng.pitt.edu/~ec2000

Visitors to the web-site can download the outcome/attribute document in its entirety or by individual outcome. Note that this list is by no means exhaustive nor is it static in nature. We consider it to be a dynamic document that will be constantly reviewed and updated much like the new approach to engineering education that ABET is promoting.

Having defined the outcomes and selected attributes, a third challenge is assessing the validity of the various methods. To do this in an effective manner, we are using a process of triangulation. The purpose of triangulation in assessment is to provide multiple measures for a particular outcome. In this way, we can learn the extent that the various methods tend to corroborate each other, and how effective each is. We also learn where they give conflicting results, a situation that would clearly call for further analysis. For example, the 'ability to work on multidisciplinary teams' may be assessed the following ways: student's own self assessment of their enjoyment for working on teams via closed-form questionnaires; through ratings of a student's peers on a team; or through the direct observation of a team by a trained evaluator. Using triangulation, all three methods would be applied; ideally this would be across two or more institutions resulting in a more thorough validation. Because, as we have noted, many of the methods and instruments currently being used in engineering education have not been fully validated in terms of content or construct, triangulation provides one means for increasing the validity of measuring the outcomes. Further, a metric/method that adequately measures a particular outcome in question may not currently exist. By triangulating the methods and metrics, one obtains multiple surrogates for the real measure of the outcome, thus providing a much needed anchor measure where none exists.

Once results from a triangulation have been obtained, results from various metrics can be correlated and statistically compared. If sufficient correlation exists among the metrics, then certain ones may be eliminated. Consequently, those metrics/measures that are efficient and cost effective then would be used to routinely assess students' progress on an outcome(s). The more in-depth, and often more costly metric only would be used periodically or with a sample of the students. This approach helps to minimize costs, and also provides a streamlined approach towards program evaluation. A goal of our project is to complete several of these triangulation studies across multiple universities and hence shed further light on the efficacy of the various assessment methodologies. In doing this we will be answering some of the research questions that we have proposed in this paper. However, in finding answers to those we may be generating more issues that engineering educational researchers will have to address.

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