ABET's Eleven Student Learning Outcomes (a-k): Have We Considered The Implications?*

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I. Introduction

There has been a great deal of intellectual and emotional debate regarding the Accreditation Board of Engineering and Technology's (ABET) minimum set of eleven student learning outcomes that are a major part of EC-2000 [1]. The issues range from serious questions as to the genesis of these outcomes, general concern regarding validity, and very legitimate concerns as to how they can best be measured to diatribes on their vagueness and even calls for their rejection. In our initial desire to satisfy the new criteria, have we become captivated with the process, as witnessed by the proliferation of continuous improvement (e.g., plan-do-act-check) models that describe the "ideal" educational path [2, 3, 4 5]? Such models have exposed engineering faculty to a cycle in the engineering educational process that is first defined, measured, compared to desired criteria or standards, and subsequently improved, and then the cycle is repeated again. In rushing to adopt this "cycle," have we overlooked an important step? Specifically, we have yet to comprehensively examine the meaning of these learning outcomes and hypothesize how our focus on each may result in an improved educational environment.

To date, five engineering schools have gone through the pilot Engineering Criteria (EC) 2000 reviews; twelve more have undergone EC-2000 reviews (fall 1998) and are waiting for final decisions. ABET had anticipated that 16 to 18 additional engineering schools would select the new criteria next year [6], but apparently almost 40 institutions have elected this option. Clearly, it is time to reflect about the foundations of these learning outcomes before too many more institutions proceed through EC-2000. No doubt, the new ABET criteria together with NSF sponsored engineering education projects (including the coalitions) have served as major catalysts for educational reform and innovation within the engineering education community. However, as a final evaluation of the coalitions also may conclude, institutional culture tends to change through evolution, not revolution. Just as educational reform takes time, developing real knowledge and competency, as denoted by the 11 outcomes, also takes time since individual intellectual growth is an evolutionary process .

The purpose of this paper is to begin the dialogue within the engineering educational community regarding how institutions can capitalize on EC-2000 to reform our educational process by supporting the development of these (and other) critical learning outcomes. As an initial impetus of this dialogue, we will focus this paper's discussion on what the literature indicates is meant by learning outcomes and what definitional issues exist. Second, we will explore the curricular planning and development implications that result from focusing on these eleven outcomes. Finally, we will propose how the integration into the curriculum of these learning outcomes impacts upon faculty-student interactions.

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II. What Are Student Learning Outcomes?

Defining student learning outcomes is dependent on the educational perspective. The term "student learning outcome" is highly interchangeable with such constructs as educational objectives [7], competencies [8], skills [9], achievement [10] and the like. This multiple treatment of terms has lead to confusion among faculty and administrators as they focus on such reform initiatives as "outcomes-driven assessment," "competency-based curriculum," and "ability-based learning." As educators, we have initiated reform actions assuming the nature of the construct without really exploring its underlying meaning. There are two issues to address when defining student learning outcomes: 1) the breadth of the construct, and 2) the level of specificity.

<u>Breadth of Construct.</u> One dilemma that educators have in accepting the outcomes construct is defining its limits; i.e., what will it encompass. Nichols [11] acknowledges the need to establish consistent terminology among educators. To Nichols, "…intended educational (student) outcomes are descriptions of what academic departments (faculty) want students to know (cognitive), think (attitudinal), or do (behavioral) when they have completed their degree programs, as well as their general education or 'core' curricula." Breaking this definition down further may help to expose some of the problems, we as educators, are having with the construct of learning outcomes.

While there are a number of relevant facets to the above definition, the delineation of three potential elements of an intended educational outcome – cognitive, attitudinal, and behavioral is most important. The inclusion of these three elements alone greatly increases the breadth of the construct. Unfortunately, Nichols provides little insight as to what is meant by cognitive, attitudinal, and behavioral. Nor does he provide guidance that would enable the instructor to translate these elements into meaningful, measurable performance criteria. Using an accounting degree program for illustration, one sample intended outcome statement is "Graduates will be experienced in the use of microcomputers for accounting procedures." The cognitive, attitudinal and behavioral elements are not explicitly alluded to in this example. At best one must infer how the statement includes these outcome elements. Yet, for our purposes, each of these elements – cognitive, attitudinal, and behavioral has substantial value and must be explored further.

How do we define cognitive-related outcomes? Krotseng and Pike [12] note that most universities relate cognitive outcomes to what the student learns in general; i.e., the "core" education courses in their academic major as well as such basic skills as writing or oral communications. With the exception of basic skills, cognitive outcomes are commonly related to knowledge acquisition. In addition, researchers acknowledge that there is increasing attention in higher education to such higher-order cognitive skills as critical thinking [13]. The eleven learning outcomes, as specified by ABET, appear to cut across all three elements. For example, " knowledge of contemporary issues" (outcome "j") is a straightforward reference to knowledge acquisition. "An ability to identify, formulate, and solve engineering problems" ("e") can refer to higher-order thinking skills. While "an ability to use the techniques, skills, and modern engineering tools…" ("k") directly implies a skill orientation.

The measurement of student attitudinal-related outcomes provides considerable information on the effectiveness of an academic program [14,15]. Most attitude measurement is focused on how students' attitudes, including their state of mind and values, are related to institutional-level performance and effectiveness. This is typically accomplished using either closed form questionnaires, one-on-one interviews and/or focus groups. The results are usually analyzed at an institutional level, and are only occasionally applied on an individual or small group level. However, as Besterfield-Sacre, Atman and Shuman have demonstrated, student perceptions of their abilities can have an influence on subsequent learning as well as such important institutional issues as retention [16]. Although the EC-2000 outcomes do not explicitly incorporate the concept of "feelings" within their construction, they do advocate a need for "valuation" [17] of certain aspects of the engineering profession. This "valuation" requirement is delineated by several outcomes (e.g. "…professional and ethical responsibility," "…the impact of engineering solutions in a global and societal context," and "…life-long learning").

Behavioral–related outcomes have become increasing common in the classroom [18]. These can be defined as an individual's action or reaction to either an external or internal stimuli. In the engineering context, behavior is seen as the manifestation (i.e., application) of what the student has learned through an educational intervention. In essence, behavioral aspects are those skills engineering students possess. A faculty member or co-op employer can readily observe the student's application of knowledge that has been transmitted through the educational process. By adding this element to our construct, we are positing a critical aspect: knowledge must not only be acquired but must also be applied in relevant situations.

By integrating these three key elements (cognitive, attitudinal, and behavioral), we have a comprehensive view of a specific learning outcome. Thus we can extend Nichols' definition to a true learning outcome *integrates* the cognitive, attitudinal and behavioral components. True learning outcomes are a demonstration that knowledge does not exist apart from application. In fact, they are tightly coupled. The attitudinal element indicates that the individual not only is capable of doing 'engineering work' but also embodies values of the profession.

<u>Level of Specificity.</u> Descriptions or attributes of the student learning outcomes vary greatly. Some examples are very general and holistic using such words as "understanding," "comprehending," and "applying." Other statements are narrowly focused with descriptors such as "synthesizing," "organizing," and "enumerating." The EC-2000 learning outcomes meet the former criteria, and, not surprisingly, most common complaints by educators focus on their vagueness. While we agree that these are vaguely constructed statements, there is a positive side. These broadly written student learning outcomes are designed to allow individual engineering programs to integrate them into their particular objectives and resultant curricula. This flexibility suggests a sensitivity on ABET's part to unique institutional missions and program differentiation as opposed to having a "cookie-cutter" set of engineering programs. The designated eleven outcomes can serve as a foundation for all engineering programs. However, each program must further define the eleven outcomes when they are applied to the specific setting, and no program should necessarily limit itself to the specified outcomes.

Nevertheless, the lack of construct specificity poses several problems. First, consensus is required if successful implementation is going to follow. Faculty and administrator consensus on definitions, performance criteria and assessment processes are required if learning outcomes are to be integrated effectively. This is true for both vertical integration within a program and horizontal integration across all the institution's engineering programs. If faculty cannot make the connections across courses, it will be difficult to transfer knowledge, behavior and attitudes across the curriculum [19]. Second, to properly recast each outcome into measurable descriptions that will result in usable assessment results requires sufficient expertise, resources, and time. This often cumbersome and difficult task for many engineering faculty is only one initial step in the overall preparation for the new accreditation.

<u>A Working Definition.</u> Based on the preceding discussion, an operational definition of student learning outcomes (relevant to engineering education) is needed to properly evaluate engineering programs. We proposed that *student learning outcomes are observable and measurable manifestations of applied knowledge*. It is our contention that true learning is reflected through the action and behavior of the individual. The cognitive processes or attitudes of individuals cannot be separated from their behavior and attitudes. In fact, as discussed later, true learning cannot be measured without observable behavior. Each of the EC-2000 learning outcomes must reflect the integration of the cognitive and behavioral – the knowing and doing. It is not enough to have " knowledge of contemporary issues." The individual must be able to demonstrate that this knowledge can be applied as one encounters new problems and attempts to achieve solutions (whether in engineering or in another context).

III. Implications for Curricular Planning and Development

The new focus on learning outcomes has initiated debate concerning the trade-off between content and process. Specifically, given a limited amount of class time, how should an instructor balance teaching students the essential knowledge required within a specific field against developing basic and higher order skills that can be used across disciplines? Certainly, this is not a new debate [20]. No matter what position one takes in this argument, the issues can have substantial impact upon the program's curriculum.

If today's educators shift focus from subject matter to student learning outcomes, the implications for curriculum planning and design will be dramatic. First, at the course-level, faculty will be compelled to re-prioritize educational objectives to reflect both a diverse set of student skills and requisite subject matter knowledge. As with content knowledge, cognitive and behavioral skills are acquired over time, although much needs to be learned about this process. For example, we need to better understand how engineering students develop as problem solvers and designers. Hence, not only must faculty determine the proper complexity of subject matter to be presented, now they also must ascertain the appropriate level of skills to be acquired based on the student population in question. While engineering educators have been implicitly doing this for sometime, the focus on outcomes now requires it to become explicit.

This new focus on student learning outcomes will have an impact on curriculum at the program level. The traditional way of building an engineering curriculum is based on providing a foundation in the sciences, adding engineering science and then introducing program subject matter with increasing levels of depth. A parallel process exists for skill development, particularly for acquiring the important engineering design skills. Here, one starts with freshman experiencing simple design processes. By the senior year, the student is expected to incorporate extensive technical knowledge into a capstone design project. In terms of student learning outcomes, how does faculty define appropriate levels of mastery from lower to upper division curricula? At the program level, the curriculum will truly become integrated as a result of focusing on student learning outcomes. For example, at the New Jersey Institute of Technology, the departmental faculty were asked to review ABET-related learning outcomes and prioritize them across the curriculum [21]. The result clearly demonstrated that the conceptualization of specific learning outcomes changed over the course of the curriculum.

The focus on learning outcomes reinforces the need for cross-discipline and cross-institutional collaboration. Not only must faculty and staff support vertical integration within a discipline; they need to facilitate horizontal integration across disciplines. This requirement may provide engineering educators with their greatest EC-2000 challenge [22]. Cross-discipline collaboration is not a cultural artifact. Academic departments are structured much akin to silos, protected and insular, as has been pointed out when the TQM movement challenged academia eight years ago [23]. Unfortunately, this organizational structure acts as a barrier to academic collaboration and curriculum coherence across various disciplines [24]. There are very few examples of institutions that have crossed these barriers in their search to implement a common learning outcome program. Alverno College [25], a liberal arts institution in Wisconsin, has spent much of the past 25 years tackling this daunting task. From all evidence, the focus on a common set of learning outcomes has had a positive effective at Alverno building strong constituent support for their "ability-based" curriculum.

Formal processes should be established to facilitate faculty discussion and debate on student learning outcomes, their definitions and fit across the students' whole educational experience. Several institutions implemented formal planning processes that foster cross-departmental collaboration in defining educational objectives and outcomes [26]. By structuring sessions where all departments are involved, the faculty is better able to understand what colleagues are attempting to achieve in their programs. Through such discussion, faculty can begin to see common objectives and outcomes across programs. This is a critical first step towards curriculum coherence.

IV. Implications For Faculty And Students In The Classroom

There are several ramifications when faculty adopts a student learning outcome focus. With a shift towards student-centered educational objectives and individual long-term development of knowledge and behavior, the style of faculty-student interaction changes. Key issues to contemplate include faculty development and student active participation in the learning process.

From the instructor's perspective, familiarity with areas outside their discipline becomes necessary. Faculty, often educated in narrow engineering disciplines, must become reasonably knowledgeable in a number of suddenly complementary areas and, at the same time, introduce writing and oral pedagogy, team dynamics, societal and global concerns, and professional ethics. While faculty may not have had a primary responsibility to teach such content, sufficient background and coordination with disciplines outside engineering will enable instructors to reinforce what students are learning in other parts of the curriculum. Felder [28] provides an interesting instructional model for addressing the Engineering Criteria 2000. Under each of the eleven student learning outcomes, he enumerates several educational activities to be implemented in the classroom. By following this suggested model, the instructor is asked to write instructional objectives, create problems with social and ethical scenarios, grade portfolios of design tasks, form heterogeneous teams, etc. Each of these activities requires a background in areas beyond traditional engineering and science subject matter. Perhaps the best example of this to date is the experience of those faculty who have developed and are teaching integrated curricula, primarily at the freshman level [29].

As previously discussed , faculty will also need to have a reasonable understanding of what other courses are trying to achieve in terms of learning outcomes. Real development of knowledge and behavior cannot occur unless it can be applied in multiple contexts [30]. For this to occur, faculty will require sufficient opportunity to review what colleagues are planning and doing in their courses. Both by necessity and desire, faculty involved with integrated curricula are well positioned to reach beyond their discipline to make the integrated concept work and improve student learning. The very encouraging news is that many of these faculty are, in fact, doing just that [31].

The very nature of the ABET learning outcomes influences the way that faculty will approach performance assessment and the process of evaluation. Since the demonstration of these outcomes involves both knowledge acquisition and behavior, assessment processes themselves must be active, reflective, and developmental. Faculty need to become familiar with the wealth of alternative assessment processes that already exist [32,33]. In general, assessment in the classroom will become more frequent, open-ended, and bilateral between faculty and students. Students also will take a more active role in their own assessment and that of their peers.

The importance of feedback when focusing on outcome based learning is critical. In short, outcome based learning will be ineffective without it; hence the development of continuous improvement process models previously described. Faculty will need to integrate student performance feedback into the classroom learning environment. This integration will have several implications. First, faculty will need to become more involved in working with individual students and student teams in order to obtain timely, valid information regarding the achievement of specific learning objectives. This increased involvement will be time-intensive and will invariably conflict with the current pre-occupation with content. It will cause additional consternation at research universities, particularly among untenured faculty. Second, through its implicit requirement, faculty will communicate and interact with students in a more interpersonal manner. This increased interpersonal interaction can only have a positive effect on learning [34].

V. An Initial Step Towards Transferring Student Learning Outcomes to the Curriculum and Classroom

Earlier, we provided a working definition for student learning outcomes. The next step is to operationalize each EC-2000 outcome with respect to Nichols' key elements. By operationalizing each outcome into a set of measurable attributes, engineering programs can better focus on curricular planning and classroom learning. However, providing construct specificity to the outcomes is not straightforward. Under NSF funding we propose to address these problems by developing a set of measurable attributes for each outcome using a framework based on accepted educational research[†].

We have expanded on Nichol's cognitive, attitudinal, and behavioral elements using a modification of Bloom's cognitive taxonomy [35] with Krathwohl's affective domains [36] coupled with the use of learning verbs derived by McBeath [37]. When complete each outcome will be expanded within each key element: (1) knowledge and comprehension (cognitive), (2) application, analysis, synthesis, and evaluation (behavioral), and (3) valuation (attitudinal). One objective is to present a comprehensive set of possible attributes based upon our collective experience; a thorough literature review; interviews with engineering faculty, and industry practitioners.

Figure 1 provides a partial example of the operationalized outcome "an ability to design and conduct experiments, as well as to analyze and interpret data." The figure describes the expanded elements and their definitions along with operational verbs for each particular element. The example outcome is first broken down into more discrete components. In this case, there are four components: design experiments, conduct experiments, analyze data, and interpret data. Figure 1 specifies plausible attributes for each element for the component "Design Experiment."

VI. Conclusions

We have attempted to initiate a dialogue among the engineering education community on the implications of adopting the eleven student learning outcomes as prescribed by the Accreditation Board for Engineering and Technology. While obviously biased in a supportive direction, this should not preclude the notion that the above issues contain difficult challenges. An initial challenge includes achieving consensus on meaning and translation into specified learning outcomes. Many institutions are jumping on the continuous improvement bandwagon without first addressing these two tasks. While institutional mission and program objectives will drive local definitions, there are several advantages and synergies to be enjoyed by reaching some degree of convergence on what we mean by these eleven outcomes. The approach suggested here may provide relief for the many engineering schools undertaking this challenge.

The second challenge targets the culture and structure of our educational institutions. Outcomes-based education can not be embedded in our institutional fabric without properly aligned structures, policies, and practices. Concepts such as curriculum coherence and cross-disciplinary collaboration cannot occur until departmental boundaries are removed or at least become more porous.

The third challenge is the willingness of students and faculty to change their behavior and habits in the classroom. Until the idea of increased intensive interaction between faculty and students can be embraced, outcome-based education will continue to be the subject of debates among educators. Fortunately, spurred in part by the coalitions, industry and ABET, there is a small, but increasing number of examples that will greatly facilitate the resolution of these debates in what we believe will be a most positive direction.

[†] Other members of the team working on specifying these attributes include C.J. Atman (U. of Washington), R. Miller and B. Olds (Colorado School of Mines), G. Rogers (Rose-Hulman) and H. Wolfe (U. of Pittsburgh).

Figure 1. Partial Example of the Outcome "An Ability to Design and Conduct Experiments, as Well as to Analyze and Interpret Data"

Definitions	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	Valuation
Bloom's Definition:	Recall / Articulation of knowledge: terminology, "facts", methodology, conventions, processes, criteria, principles	Understanding of knowledge without synthesizing (creating new knowledge or understanding relationships): translation, interpretation, extrapolation, prediction—(meaning making)	Use of knowledge in a different situation: application of principles to describe a phenomenon, application of theory to describe trends (select and use knowledge in a new application)	Critique/analysis to clarify understanding and build meaning: identify elements to decompose, identify relationships, organize information systematically (examine)	Combination of pieces to form a whole: to produce new knowledge, to develop a systematic plan to test ideas, induct, deduct, produce	Qualitative or quantitative judgment based on stated criteria: accuracy, consistency, external standards/theories/generalization	Sensitivity/willingness to receive (awareness w/o assessment, willingness to suspend judgment); Actively respond (comply, commit, internal satisfaction); Value (acceptance of worth, preference); Organize (when values conflict)
Verbs:	Define, arrange, list, order, recognize, state	Classify, describe, identify, indicate, restate, translate, review	Apply, demonstrate, employ, interpret, use, solve	Analyze, calculate, categorize, compare/contrast, differentiate, experiment, examine, question	Assemble, construct, create, develop, formulate, manage, organize, plan, prepare	Assess, compare, estimate, judge, predict, rate, select, support, evaluate	Accept, challenge, defend, respect, question, support, enjoy
Outcome Element: *Designing Experiments*	Recognizes applicable analytical models, or possible simulators (e.g. physical, digital, continuous, other format). Defines the existing theory/history	Indicates how existing theory/history differs/complements current question Identifies the variables in questioned (controllable, level of variation, impact with other variables)	Uses existing theory/history in developing an experiment Constructs an appropriate hypothesis or problem statement Determines the constraints and assumptions for the experiment - cost, time, equipment Seeks information for experiment from multiple sources	Examines the measure(s) of effectiveness by which the outcome or the alternative will be evaluated – cost, quality, value, time to complete, feasibility Estimates experimental uncertainties	Formulates the control and evaluating alternatives of the experiment Develops contingency plans	Determines the data that are appropriate to collect Specifies and justifies the assumptions given test conditions	Accepts the limitations and extensions that a model built can be used to represent the system

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