A Bottom-Up Outcome-Based Learning Assessment Process for Accrediting Computing Programs

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Abstract—The push for a *culture of evidence* that guides improvement in higher-education has made outcome-based assessment a necessity. Furthermore, the recent move by ABET's CAC into more rigorous assessment has caused anxiety among faculty and administrators. Assessment leaders face various challenges including *process design and implementation, faculty buy-in,* and *resources availability*. This paper presents a bottom-up outcome-based assessment approach that facilitates faculty participation while simplifying the assessment and reporting processes. The proposed approach has been implemented and used for the successful accreditation of a computer science program, and can be easily adapted to any higher education program.

Keywords: Program Outcome Assessment, ABET Accreditation

I. INTRODUCTION

Assessing learning has been at the heart of higher education ever since its inception; *grades* as well as *retention* and *graduation rates* have always been used as measures of students performance. However, over the past 40 years, there has been an increasing pressure on higher education in order to create a *culture of evidence* that guides improvements in teaching and learning. While the demand to establish such a culture appears to be new, it has a long lineage and can be traced back as far as 1936 when the *Carnegie Foundation for the Advancement of Teaching* made a strong argument for improving higher education through a process that includes setting up acceptable standards and devising appropriate methods of measuring achievement while introducing flexibility in educational offerings [1]. Assessment of students learning has consequently progressed from the rise and development of standardized tests, to the assessment of learning for general and graduate education, and finally to the current era of external accountability [2]. A recent study by the *National Institute for Learning Outcomes Assessment* has concluded that the most common uses of assessment data are to primarily prepare for program and institutional accreditation [3]; among all schools, the least common uses for assessment data are for making daily resource decisions, admissions and transfer policies, and faculty/staff performance. The study also noted that most institutions conduct learning outcomes assessment on a *shoestring* while gaining faculty involvement and support in assessment remains a major challenge. The push for the

"culture of evidence" has been capped by a new wave of outcomes-based assessment wars among professional and regional accreditation agencies. For example, the senior college commission of the Western Association of Schools and Colleges (WASC) adopted changes that shift the focus from institutions being merely engaged in assessment to being about what the results are and what they mean [4]. ABET accredits computing and engineering programs which need to demonstrate, among others, that they meet a set of program outcomes under criterion 3 (known as the ABET's *a-k* in computing and engineering, ABET's *a-j* in IS, and ABET's *a-n* in IT).

Outcomes-based assessment is a learning assessment approach where students are expected to acquire specific skills, knowledge and behavior as they progress through a course or a program [5]. Assessment can be *formative* or *summative* and is typically tackled at the *classroom level*, the *program level*, or the *institutional level*.

This paper describes an outcome-based assessment approach for accrediting computer science programs based on an effective course level assessment that facilitates and enhances faculty participation. The proposed approach is based on a bottom-up model that can be easily adapted to any program. In fact, the approach is currently being used in order to assess learning in various arts and sciences programs in the School of Arts and Sciences at the Lebanese American University. The remainder of this paper is organized as follows. Section II describes ABET computing accreditation and assessment while section III presents the proposed learning assessment and planning model. Section IV describes the assessment process and reporting while section V presents the evaluation process and closing the loop. We conclude with remarks and observations in section VI.

II. BACKGROUND

ABET's Computing Accreditation Commission (CAC) accredits computing programs that demonstrate meeting nine well defined criteria. Currently, there are a total of 344 ABET-accredited computing programs with 260, 37, 22, and 21 programs accredited under the curricula of *computer science, information systems, software engineering,* and *information technology*, respectively. ABET also currently ac-
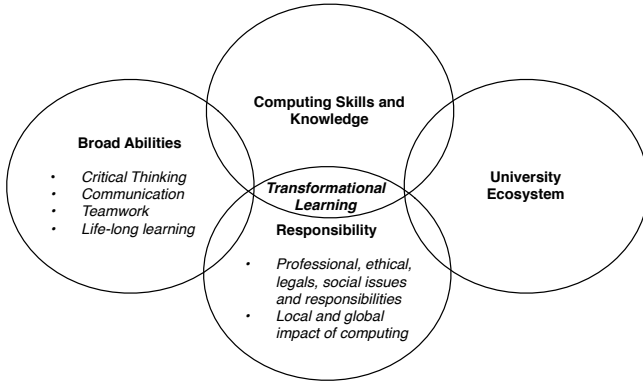
Fig. 1.   ABET Computing Learning Outcomes

Fig. 2.   Assessment Process

credits 9 programs under the general CAC criteria. Criterion 4, *continuous improvement* [6], states that an accredited program "must regularly use a appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained. The results of these evaluations must be systematically utilized as input for the continuous improvement of the program. Other available information may also be used to assist in the continuous improvement of the program." Because of its relative novelty in computing accreditation, the implementation of effective outcome-based assessment processes has caused anxiety among faculty and administrators in their quest for ABET accreditation [7].

ABET's push for a culture of evidence has demonstrated that a collegial model for curricular and pedagogical reform represents a more effective approach for improving curricula in higher education, in contrast to the recommendations of the Spellings Commission's that calls for federal reliance upon regulatory, monitoring and inducement strategies. Outcome-based assessment represents a major shift of ABET accreditation focus from curricular audit to include learning assessment by requiring that ABET accredited programs demonstrate that they meet three sets of outcomes (Figure 1). The first set includes knowledge that students should acquire in the major. The measurement of these outcomes has proven to be rather difficult since faculty within a discipline do not necessarily agree neither on the meaning of such specific outcomes nor on how to measure them. The second set of learning outcomes include broad abilities such as how to think critically, acquire life-long learning, and communicate clearly and concisely. The third set of learning outcomes relate to individual ethical and social responsibilities. When considered together and supported by a college's environmental ecology, the ABET learning outcomes should contribute to transformational learning outcomes [2].

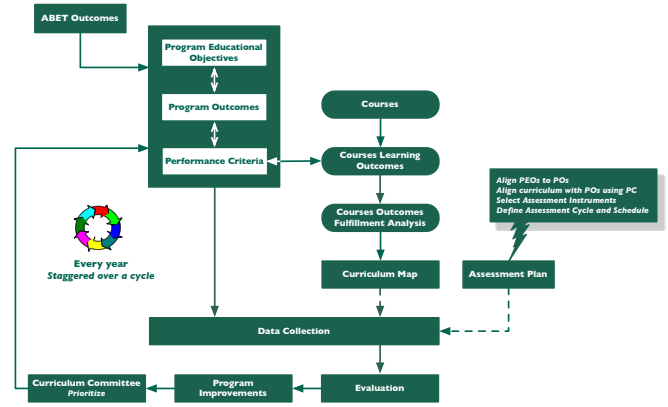The assessment process should build a body of evidence to improve the program. Such a process should evolve around the *program's mission*, *objectives*, and *outcomes*. The program educational objectives should be aligned with the needs of the program constituencies and the institution's mission. The student outcomes should be measurable, based on the needs of the program's constituencies. Furthermore, the program should develop a systematic and on-going process where clear instruments are adopted in order to acquire assessment information over time. The other caveat is that CAC requires that the program *enable* the CAC student outcomes, which may not necessarily be the same as the program's student outcomes.

Assessment instruments should be multi-faceted and include direct and indirect methods. Typically indirect methods include *students or faculty surveys*, *alumni surveys*, *external advisory boards*, *focus groups*, *exit surveys*, and *exit interviews*. Direct assessment methods include programming *assignments*, *projects*, *in-class tests*, *portfolios*, *oral presentations* and the *ETS's Major Field Test* [8], [9], [10], [11]. Blanford *et al.* [8] propose personal class assessment which is a course-based assessment tool in which the instructor writes an assessment of the course being taught. The authors also propose an assessment day as an effective way for faculty to meet, evaluate assessment results, and provide improvement recommendations. Typically each instrument has its own advantages and limitations and thus it is typically advised to mix different assessment tools for triangulation purposes [12]. Assessment should be followed by evaluation where thresholds are established in order to analyze and report the data to the stakeholders. Data are analyzed to identify problems and solutions must be proposed and implemented [13]. Crouch [5] recommends the formation of a departmental steering committee of senior faculty members to consolidate all course outcomes into a final set of outcomes.

III. COMPUTER SCIENCE OUTCOME-BASED ASSESSMENT

Established in 1924, the Lebanese American University (LAU) is chartered by the *Board of Regents of the State University of New York* and is accredited by the *New England*

Association of Schools and Colleges (NEASC). The Computer Science program was established in 1977, and currently offers degrees leading to a *Bachelor of Science in Computer Science*, and a *Master of Science in Computer Science*. Currently, the program has 217 students. In 2008, LAU embarked on accrediting all professional programs, including the computer science program. The accreditation of the computer science program was successfully completed in two years, and resulted with a wide awareness of outcome-based assessment and systematic program review and improvement. The Program implemented an efficient bottom-up outcome-based assessment process that integrates learning assessment at the course and at the program levels. The process, shown in Figure 2, includes: *assessment planning*, *the selection of performance criteria*, *curriculum mapping*, *program assessment*, *program evaluation*, and *closing the loop*.

A. Assessment Planning

Faculty participation in program assessment and curricular development remains a challenge as these time-consuming activities take faculty away from *research* and *publication* which remain at most universities highly valued in promotion, tenure, and merit-pay decisions. On the other hand, faculty feel strongly about "their" courses, which are the main strategy that are used to assess the program outcomes. Strategies are implemented for course learning outcomes in order to support the program outcomes, and ultimately the program educational objectives. Program objectives and outcomes do not need to be assessed every semester; however, it is essential that assessment activities integrate the assessment of all outcomes over the regular assessment cycle. Typically, the following are noted:

(a) Assessment should not only be used to satisfy accreditation, but also as a major internal driver for systematic program review and improvement;
(b) Learning assessment at the course level can be formative as well as summative, and is implemented over the span of one semester. It has the advantages of broad faculty involvement and easy implementation;
(c) Learning assessment at the program level, as required by ABET Accreditation, is summative. Assessment and improvements are typically implemented over a 3-4 years cycle.

In what follows, we describe the various steps involved in planning assessment in a bottom-up fashion, including the mapping of courses to program outcomes at the course outcome level, the selection of assessment instruments, performance criteria, and curricular mapping.

1) Aligning Courses and Student Outcomes: Assessment planning should start *concurrently* at the course as well as at the program level. Thus, at the course level, each course is assigned two "owners" in the form of a *coordinator* and a *co-coordinator*. The rational for having two coordinators is two-fold. On one hand, this engages experts in the area and increases faculty buy-in in assessment. On the

other hand, the coordinator and co-coordinator constitute a committee of area experts that provides oversight and broad perspective in the collection and review of the assessment evidence in the course. For each course, the committee of area experts shall:

(a) Establish and review the course learning outcomes;
(b) Select the assessment instruments that will be used to measure each course learning outcome;
(c) Establish an acceptable performance level;
(d) Oversee courses including the selection of textbooks, the monitoring of course delivery and content, the coordination of the assessment process, and the follow up with the chairperson on any issues that may arise;
(e) Collect data at the course-outcome level under the related program outcomes.

Assessment planning at the program level starts with a departmental steering committee that reviews all program objectives and outcomes in order to ensure that they are *measurable*, *realistic*, *contemporary*, and *aligned* with the School's and University missions as well as with the needs of the program's constituencies. It is recommended at this stage not to get involved in lengthy debates or controversial changes as such changes should be the output of the assessment process.

2) Assessment Instruments: The program's assessment plan should measure the program outcomes using multiple instruments in order to allow for triangulation in the assessment process. The assessment instruments vary depending on what the committee of experts is trying to learn, and on the nature of the course. The instruments that we have implemented and adopted included *embedded assessment*, *scoring rubrics*, *exit surveys*, *students meetings*, and *locally developed exams*.

3) Performance Criteria Selection: The measurement of program outcomes, especially the technical ones, has proven to be rather elusive and difficult since faculty within a discipline do not necessarily agree neither on the meaning of such outcomes nor on how to measure them. In order to resolve this issue, ABET *recommends* the use of performance criteria which are "specific, measurable statements identifying the performance(s) required to meet the outcome, confirmable through evidence."

In order to facilitate the assessment process, we use a bottom-up process where course outcomes are selected as performance criteria. Thus, courses coordinators can easily establish the relationship between student outcomes and courses outcomes using three learning levels, *introductory*, *reinforcement*, and *emphasis* levels [14]. This process is facilitated using an outcome-fulfillment form, that establishes a course map between the program outcomes and the course outcomes. This process can be facilitated using a simple "course map" that establishes a learning relationship between program outcomes and courses learning outcomes. The course map uses the following three learning levels:

- *Introduction level* where students are not expected to be familiar with the content or skill at the collegiate or

graduate level. Instruction and learning activities focus on basic knowledge, skills, and/or competencies at an entry-level of complexity.

- *Reinforcement level* where students are expected to possess a basic level of knowledge and familiarity with the content or skills at the collegiate or graduate level. Instruction and learning activities concentrate on enhancing and strengthening knowledge, skills, and expanding complexity.
- *Emphasis level* where students are expected to possess a strong and advanced foundation in the knowledge, skill, or competency at the collegiate or graduate level. Instructional and learning activities focus on the use of the content or skills in multiple contexts and at multiple levels of complexity.

4) Curriculum Mapping: Curriculum design and development is a process that requires continuous improvement. An efficient tool that is typically used in order to reveal gaps and repetitions in content is the curriculum map. The map is a matrix that identifies on one dimension the courses and on the other dimension the student outcomes. A given cell in the matrix indicates the level of correspondence between the courses and the outcomes.

Curriculum maps can be used in order to check for consistency and coherency in the program by aggregating courses in order to identify where student outcomes are enabled and at what learning level. This fine-grained mapping provides more information on the programÕs weaknesses, strengths, and areas of improvement. It does also provides the process with he optimal courses that can be used for data collection and measurement.

5) Assessment Schedule: Once the curriculum map has been finalized, the assessment coordinator collates all information and sets the schedule of the assessment process based on courses that emphasize the student outcomes. The assessment schedule includes:

(a) The student outcome to be assessed;
(b) The assessment plan for the outcome which states when the course is assessed and through which courses;
(c) The evaluation party.

IV. Assessment

A. Program Educational Objectives Assessment

As of the 2013-2014 accreditation cycle, programs are no longer required to assess the extent to which graduates achieve the *Program Educational Objectives* (PEOs). However, the program is required to instill and systematically utilize an "effective process," that involves the program constituencies for the periodic review of these program educational objectives. The program should ensure that the objectives remain consistent with the institutional mission, the program's constituents' needs, and these criteria [6].

The computer science program's educational objectives at LAU are reviewed based on a three-year cycle that focuses on the alumni who have been in the workforce or graduate

school for two to five years in addition to the Advisory Council.

B. Student Outcomes' Assessment

Once the assessment plan has been finalized and the schedule set, the *assessment officer* communicates to all course coordinators the schedule of assessment of their courses. The course coordinators are also communicated the *faculty course assessment form* that is used in order to streamline the assessment process, and which is a modified version of the FCAR that was first introduced by Estell [15] The assessment process measures the performance criteria using the appropriate instruments that were selected by the coordinators. The FCAR includes a *header*, *grades distribution*, *program outcome assessment*, *student feedback*, *reflection*, and *proposed actions for course improvement*. The FCAR makes use of the collected assessment data in order to draw conclusions regarding the students meeting the student outcomes. The effective use of FCAR should lead to a more consistent standard of teaching, learning, and assessment. The FCAR is presented to the assessment officer who shall send an annual report to the departmental curriculum committee. The departmental curriculum committee prioritizes and then sends a recommendation to the faculty.

An outcome is deemed to be met based on the dominant classification of its performance criteria. A performance criterion is classified to be *below*, *minimally meet*, *meet*, or *exceed expectations* based on the following:

1) Whenever scoring rubrics are used, a criterion is said to be met if at least 75% of the assessed students receive a score of 3 or 4 based on the following scoring method:
   (a) Beginning
   (b) Developing
   (c) Accomplished
   (d) Exemplary
2) Whenever embedded assessment is being used, a criterion is said to be met if 75% of the assessed students receive a score of at least 65% or above. Since the level questions tend to be either fairly easy or somewhat difficult.), the final threshold is determined by the course coordinators but should not be in any case less 60%.
3) Whenever a locally developed exam is administered,

Course Outcome:			
Related Student Outcome:			
Assessment Method	*Average Score*	*Performance standard*	*Percent Meeting Performance Standard*

TABLE I
ASSESSMENT PART OF THE FCAR

Performance Criteria	Strategies	Assessment Method(s)	Source of Assessment	Performance Standard	Collection Agent
PC.1: Students shall demonstrate the ability to analyze and interpret statistical data;	MTH 305	Embedded assessment. Course Survey. Exit Survey.	MTH 305	65% or equiv. / ≥ Good / ≥ Good	S. Abi Ghanem C. Nour
PC.2: Students shall be able to apply fundamental concepts of discrete mathematics in order to model computational problems;	CSC 323, MTH 207	Embedded assessment. Course Survey. Exit Survey.	CSC 323	65% or equiv. / ≥ Good / ≥ Good	H. Harmanani S. Sharafeddine
PC.3: Students should be able to describe analytically the functions of simple combinational and sequential circuits;	CSC 323	Embedded assessment. Course Survey. Exit Survey.	CSC 323	65% or equiv. / ≥ Good / ≥ Good	H. Harmanani S. Sharafeddine
PC.4: Students should be able to demonstrate the application of abstract structures such as graphs to the solution of computer science problems;	CSC 310, MTH 307	Embedded assessment. Course Survey. Exit Survey Locally Developed Exam	MTH 307 and CSC 310	65% or equiv. / ≥ Good / ≥ Good / 70%	C. Nour F. Abu Khzam

Fig. 3. Sample Assessment Plan for Student Outcome 1

a criterion is said to be met if 75% of the assessed students receive a score of at least 70% or above.

4) Whenever surveys are administered, a criterion is said to be met if 75% of the assessed students are at the good or above levels.

We next map the percentages that were received per performance criteria to *numeric score*, from 1 to 4, as shown in Table II in order to be able to conclude whether an outcome is met or not. The scores are next aggregated based on a simple weighted formula where each performance criteria is assigned a weight, $w_i, i = 1, 2, ..., n$, and an aggregation rule $R(V) = \text{sign} \sum_{i=1}^{n} w_i v_i$. Thus, the outcome is deemed to be met or not based on the output of the weighted majority function.

V. Evaluation and Closing the Loop

The last step in the outcome-based assessment is to analyze the collected data and to feed into the program possible identified improvements. The process should be documented and reported for the purpose of ABET accreditation, and is typically driven by a departmental curricular committee. Changes may include the adjustment of course contents, the addition or deletion of courses,

and the acquisition of equipments or facilities, to cite few. One of the challenges during this phase is the ability to prioritize the proposed improvements and to find the proper balance between program needs and financial and academic constraints.

VI. Conclusion

We have presented a systematic process for outcome-based assessment that has led to the accreditation of the computer science program at the Lebanese American University. The process is based on a bottom-up approach that minimizes faculty's effort and increases faculty buy-in. The process can be easily automated and efficiently implemented.

Percent Student Meeting Criterion	Classification	Weight
⩽ 69%	Below Expectations	1
70%−79%	Minimally Meet Expectations	2
80%−89%	Meet Expectations	3
90%−100%	Exceed Expectations	4

TABLE II
Scoring Mapping

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