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An outcome-based assessment process for accrediting computing programmes

Haidar M. Harmanani

Department of Computer Science and Mathematics, Lebanese American University, Byblos, Lebanon

ABSTRACT

The calls for accountability in higher education have made outcome-based assessment a key accreditation component. Accreditation remains a well-regarded seal of approval on college quality, and requires the programme to set clear, appropriate, and measurable goals and courses to attain them. Furthermore, programmes must demonstrate that responsibilities associated with the goals are being carried out. Assessment leaders face various challenges including *process design and implementation, faculty buy-in*, and *resources availability*. This paper presents an outcome-based assessment approach that facilitates faculty participation while simplifying the assessment and reporting processes through effective and meaningful *visualisation*. The proposed approach has been implemented and used for the successful ABET accreditation of a computer science programme, and can be easily adapted to any higher education programme.

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1. Introduction

Assessing learning has been at the heart of higher education ever since its inception, and has progressed from the rise and development of standardised tests, to the assessment of learning for general and graduate education, and finally to the current era of external accountability (Shavelson 2010). While assessment, accountability, and continuous improvement have recently become *catchphrases* in higher education, it was in a study at the turn of the last century that the *Carnegie Foundation for the Advancement of Teaching* pioneered the notion of learning and achievement in education (Kandel 1936). The study proposed a mechanism for longitudinal data collection that indexed both achievement and learning for a cohort of high school seniors.

The report by the *Commission on the Future of Higher Education* appointed by US Secretary of Education *Margaret Spellings* on the future of higher education has been a major catalyst in the recent push for learning assessment (US Department of Education 2006). The report calls for measuring *meaningful* student learning outcomes using quality-assessment data from instruments and standardised tests such as the *Collegiate Learning Assessment (CLA)* test in order to assess *critical thinking*, *problem solving*, and *communication skills*, and calls on accreditation agencies to make performance outcomes a priority over inputs or processes. Most recently, public officials in the United States are advocating the use of completion rates, graduates' earnings, and graduates' advanced degrees as accountability measures (Kington 2014). Furthermore, the European Commission has recently issued a report recommending that quality assurance be used to assess whether the skills college students acquire really meet labour market needs (European Commission 2014).

CONTACT Haidar M. Harmanani hmh@case.edu

Although assessment should be considered as a framework for focusing faculty attention on student learning, a study by the *National Institute for Learning Outcomes Assessment* has concluded that the most common uses of assessment data are to primarily prepare for programme and institutional accreditation (Kuh and Ikenberry 2009). In fact, the study notes that the least common uses for assessment data are for making daily resource decisions, admissions and transfer policies, and faculty/staff performance. Furthermore, 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 wave of outcome-based assessment competition 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* (Lederman 2011). The Council of Social Work Education (CSWE) requires a competency-based curriculum and requires that the programme evaluate the extent to which the competencies have been met. CSWE also requires that the assessment data are continuously used in order to enhance the attainment of programme competencies (Council on Social Work Education 2016). ABET accredits computing and engineering programmes that demonstrate, among others, that they assess and evaluate the extent to which a set of *predefined* student outcomes are being attained (Milligan 2015).

This paper describes a bottom-up outcome-based assessment approach for accrediting computer science programmes based on an effective course-level assessment that facilitates and enhances faculty participation. The method also proposes an effective visualisation approach that makes it easy to report and use assessment data in order to inform and promote curricular changes. The remainder of this paper is organised as follows. Section 2 provides a brief introduction to outcome-based education (OBE) and assessment while Section 3 introduces ABET accreditation and the steps involved. Section 4 presents the computer science outcome-based assessment process. Section 5 presents the assessment results visualisation and evaluation. We conclude with remarks and observations in Section 6.

2. OBE and assessment

OBE is a relatively new reform model of education that is designed to promote *desired* and *meaningful* learning outcomes. The learning outcomes should be *specific*, *observable*, and *measurable* , and describe the expected result of learning as a starting point of the curriculum (Driscoll and Wood 2007). The model adopts a student-centred learning philosophy and fosters continuous attention to student learning by promoting accountability (Maki 2012).

Assessment focuses on quality assurance by measuring student learning outcomes in the academic programme. Assessment can be *formative* or *summative* and is typically tackled at the *classroom level*, the *programme level*, or the *institutional level*. Formative assessment is continuous and aims at providing feedback to improve what is being assessed at the course or programme level. In contrast, summative assessment occurs at the end of the course or the programme with the objective of providing an evaluative summary. Assessment at the classroom level aims at probing using formative and summative questions what students are learning within as well as across courses, and how well they are meeting the outcomes of a course. Assessment at the programme level aims at answering using summative questions whether the programme 's courses are organised in a coherent manner, and how well they contribute to the student outcomes.

Assessment in OBE lends itself to a continuous improvement process with an emphasis on demonstrating *skills*, *competencies*, and *knowledge*. Typically, students are expected to acquire specific skills, knowledge and behaviour as they progress through a course or a programme (Maki 2012). Evidence is next collected and judgement is made on whether the assessment indicators have been met (Al-Yahya and Abdel-halim 2013; Harmanani 2013; Robinson and Shoop 2015) . Assessment indicators are measured using multi-faceted instruments that 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 *standardised assessment tests* such as the *CLA* (Shavelson 2008) and the *Educational Testing Service's (ETS) Major Field Test* (Blanford and Hwang 2003; Sanders and McCartney 2003, 2004; Dick 2005). Blanford and Hwang (2003) 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 (Rogers 2009). Assessment should be followed by evaluation where thresholds are established in order to analyse and report the data to the stakeholders. Data are analysed to identify problems and solutions must be proposed and implemented (Maxim 2004). Crouch and Schwartzman (2003) recommends involving the senior faculty in the department through a steering committee that would consolidate the course outcomes into a final set of outcomes.

3. ABET accreditation

ABET is an organisation that is recognised by the Council for Higher Education Accreditation (CHEA) as the sole agency responsible in the United States for the accreditation of educational programmes leading to degrees in applied science, computing, engineering, and engineering technology. ABET accreditation is a peer-review process that involves *faculty*, *researchers*, and *practitioners* in the review of evidence from the programme under review in order to ensure compliance with the accreditation criteria. Most importantly, the process promotes the dissemination and exchange of best practices by making sure that the programme has in place processes that ensure improvement and quality assurance. Academic accountability (Shavelson 2010) is best visualised using a multi-faceted view representing *accreditation*, *assessment*, and *academic audit* (Figure 1). Although accreditation is used by employers, governments, and the public for various reasons and objectives, assurance of academic quality and student success remain paramount.

The ABET accreditation process starts with a formal *Request For Evaluation* and takes a minimum of 18 months to be completed. The institution next submits a self-study report for the programme that is to be reviewed by July 1 of the calendar review year. ABET next arranges for an on-site review that is conducted in order to verify that the programme is in compliance with the appropriate accreditation criteria and the *Accreditation Policy and Procedure Manual*. The self-study is based on a questionnaire that is updated on a yearly basis by ABET. As of 2012, ABET requires a readiness review from programmes seeking initial accreditation that are housed in institutions which currently have no ABET-accredited programmes in that same commission.

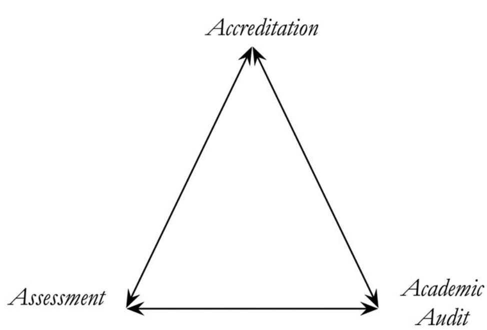


Figure 1. Academic accountability.

ABET's *CAC* accredits computing programmes that demonstrate satisfying eight different criteria that cover the following areas: *students*, *programme educational objectives*, *student outcomes*, *continuous improvement*, *curriculum*, *faculty*, *facilities*, and *institutional support* (Peterson 2009; ABET 2016). Furthermore, *computer science* programmes, *information technology* programs, and *information systems* programs need to demonstrate satisfying specific programme criteria that are implied by the programme title. Currently, there is a total of 407 ABET-accredited computing programmes (Figure 2) with 304, 53, and 37 accredited computer science, information systems, and information technology, respectively. There is a total of 47 international computing programmes or 13.5% that are currently accredited by ABET.

ABET's push for a culture of evidence has demonstrated that a collegial model for curricular and pedagogical reform represents an effective approach for improving curricula in higher education. Outcome-based assessment represents a major shift of ABET accreditation focus from curricular audit to include learning assessment by requiring that ABET-accredited programmes demonstrate that they meet three sets of outcomes (Figure 3). The first set includes technical 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 critical thinking, life-long learning, team work, and oral and written communication. The third set of learning outcomes relate to ethical and social responsibilities. When considered together and supported by the college's environmental ecology, the ABET learning outcomes should *lead* to transformational learning that induces experiences and shapes the learner by producing a significant impact, or paradigm shift, which affects the learner's subsequent experiences (Clark 1993).

4. Computer science outcome-based assessment process

ABET's criterion 4, *continuous improvement*, is a cornerstone of ABET accreditation, and is concerned with programme assessment, evaluation, and continuous improvement. The criterion states that an accredited programme needs to 'regularly use appropriate, documented processes for assessing and evaluating the extent to which the student outcomes are being attained'. Furthermore, the criterion requires that 'the results of these evaluations must be systematically utilised as input for the continuous improvement of the programme. Other available information may also be used to assist in the continuous improvement of the programme ' (ABET 2016). 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's accreditation (Cook, Mathur, and Visconti 2004).

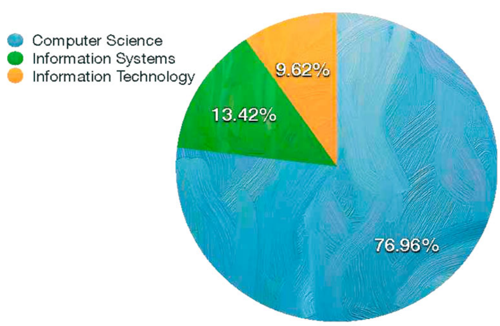


Figure 2. *Computing Accreditation Commission* (CAC) accredited computing programmes.

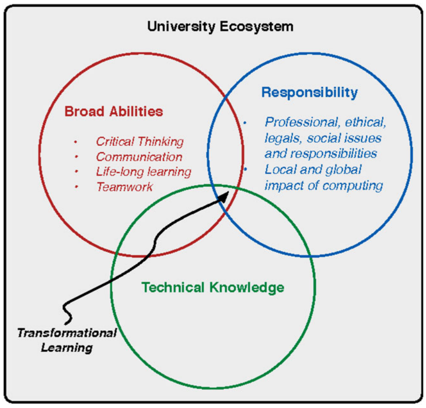


Figure 3. Contribution of ABET student outcomes to learning within a university ecosystem.

4.1. Assessment planning

Shavelson (2010) defines learning as the change in a person's knowledge and behaviour over time due to experience rather than maturation. Therefore, assessment planning (Figure 4) is concerned with the design and development of appropriate activities or tasks that can *measure* the processing of mental information to successful performance (Carroll 1993). The assessment plan should include a data collection schedule and evaluation for continuous improvement. Ideally, data collection should be longitudinal and collected at various stages of the learning process.

Faculty involvement and participation in the planning assessment is paramount for ABET accredited programmes. Assessment planning should start *concurrently* at the course as well as at the

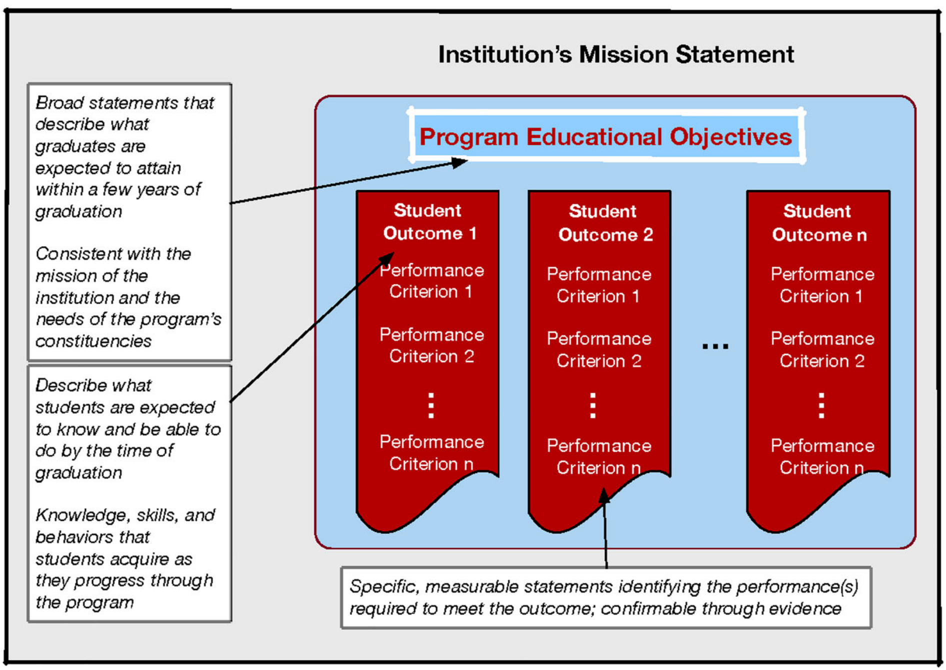


Figure 4. Assessment planning: programmes should set clear, appropriate, and measurable outcomes and courses to attain them. Programmes must demonstrate that responsibilities associated with the outcomes are being carried out.

programme level. Thus, at the course level, each course is assigned an ‘owner’ in the form of a *coordinator*. The rational for having a coordinator is twofold. On the one hand, this engages experts in the area and increases faculty buy-in in assessment. On the other hand, the coordinators constitute committees of area experts that provide oversight and broad perspective in the collection and review of the assessment evidence in various courses. Assessment planning at the programme level starts with a departmental review of the programme educational objectives and student outcomes in order to ensure that they are measurable, realistic, contemporary, and aligned with the university’s mission as well as with the needs of the programme ’s constituencies. It is recommended at this stage not to get involved in controversial debates as changes should be the output of the assessment process.

4.1.1. Programme educational objectives.

Programme educational objectives are statements that describe what the graduates are expected to attain within a few years of graduation. ABET accreditation criterion 2 requires that the objectives are consistent with the mission of the institution and the needs of the programme ’s various constituencies. ABET does not require the assessment of the programme educational objectives but rather a cyclical review that ensures that they continue to meet the needs of the programme ’s constituencies. Finally, it should be noted that ABET does not have any specific requirements for the development or the language of the programme educational objectives. However, a typical issue that programmes undergoing accreditation suffer from is wording the programme educational objectives in a similar way to student outcomes so that they describe qualities students possess at the time of graduation.

4.1.2. Student outcomes.

Student outcomes are statements that describe what the students are expected to know and be able to do by the time of graduation. The student outcomes should be*measurable*, *meaningful*, and based on the needs of the programme ’s constituencies. While ABET’s Engineering Accreditation Commission (EAC) specifies a set of predefined outcomes, known as the (a–k) outcomes (Figure 5), that students in a programme must meet, the CAC takes a more flexible approach. Thus, computing programmes can determine and define their own outcomes that are assessed, periodically reviewed and revised. The programme must also *enable* the students in the programme to attain the computer science (a–k) outcomes by the time of graduation.

Although programmes may opt to develop their own outcomes, most computer science programmes are nowadays adopting the (a–k) outcomes as their own outcomes. The advantage of this approach is that the programme would not have to deal with two different sets of outcomes

(a) An ability to apply knowledge of computing and mathematics appropriate to the program’s student outcomes and to the discipline
(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution
(c) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs
(d) An ability to function effectively on teams to accomplish a common goal
(e) An understanding of professional, ethical, legal, security and social issues and responsibilities
(f) An ability to communicate effectively with a range of audiences
(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society
(h) Recognition of the need for and an ability to engage in continuing professional development
(i) An ability to use current techniques, skills, and tools necessary for computing practice
(j) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices
(k) An ability to apply design and development principles in the construction of software systems of varying complexity.

Figure 5. ABET CAC defines a set of student outcomes, known as the (a)–(k), that programmes should enable.

whereby one set is assessed while demonstrating that the programme enables the attainment of the other set. The other advantage is that computer science programmes that are housed in engineering schools may prefer the use of the same language and processes across all programmes. Data maybe collected from the student outcomes either directly or through performance criteria or indicators. We use the latter as it provides the programme with more information for continuous improvement opportunity. Student outcomes do not need to be assessed on a yearly basis; however, it is essential that assessment process integrate the assessment of all outcomes over the regular assessment cycle. The assessment plan should be summative and implemented over a 3–4 years cycle.

4.1.3. Assessment instruments.

ABET accreditation requires that the assessment process build a body of evidence and be a major internal driver for systematic programme review and improvement. In order for the assessment to be meaningful, it is recommended to use multiple instruments so that to allow for triangulation. The assessment instruments vary depending on the nature of the student outcome and on what the programme is trying to learn. The instruments that we have implemented and adopted are as follows:

(1) *Soft Skills Assessment Instruments*: ABET accreditation criteria require the assessment of various professional skills that include broad abilities, such as ethical and societal responsibility, critical thinking, life-long learning, team work, and oral and written communication. These skills are best assessed in a capstone project using students' activities that include case studies and scenarios that explore a contemporary problem. The case studies are tackled in teams and involve developing a meaningful solution approach while taking into consideration ethical and societal considerations. The groups present the findings, and the performance indicators or criteria are assessed based on a set of scoring rubrics. Although we have developed our own case studies and rubrics, various approaches have been proposed in the literature (Schmeckpeper et al. 2014).
(2) *Locally Developed Exams*: Local exams are specific exams that are locally designed and developed for use in the assessment process (Banta and Schneider 1986). In this case, a specific performance criterion is assessed using a minimum of seven multiple-choice questions (or at least two word problems). Local exams can be used for formative as well as for summative assessment purposes.
(3) *Embedded Assessment*: Embedded assessment is an assessment mechanism where questions related to specific student outcomes are embedded within exams, homework, projects, and assignments. Exam questions that can be used to assess specific courses outcomes are typically *isolated*, *graded*, and *reported*. The exam is structured such as to facilitate the data collection the outcomes.
(4) *Exit Survey*: Exit surveys assess all performance criteria using survey questions and based on a *Likert* scale. The instrument may also survey the students on advising, facilities, course offering, and advising in order to support other ABET criteria. Exit surveys are followed with *exit interviews* that focus on problematics issues that arise in the surveys.
(5) *Students Meetings*: Students meetings are essential as they provide students with a space to share their perspective on topics of concern. The instrument typically mimics the process of a town hall meeting by providing a structure for different perspectives on a topic to be heard.

In addition to the above instruments, there are various *standard assessment exams* that can be used to assess content knowledge and retention by students at the completion of their major field of study, and are typically used when comparisons with a national group is required. This includes the *MFT* that assesses the mastery of concepts and principles and knowledge by graduating computer science students. Other standard assessment exams that measure critical thinking, analytic reasoning, problem solving, and written communication skills include the *CLA*, and to some extent the *Area Concentration Achievement Test (ACAT)*.

4.1.4. Performance criteria or indicators.

Faculty participation in programme 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 strategies that are used to assess the student learning outcomes. Furthermore, the measurement of student 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 facilitate this issue, we *recommend* the integration of the assessment process in the teaching and regular course assessment process.

We use a bottom-up approach where a meaningful subset of the course outcomes are selected to be used as assessment indicators or criteria, which are measurable statements that identify the performance required to meet the outcome. Thus, for each student outcome, course coordinators nominate a set of course outcomes that are to be used as performance criteria or indicators as shown in Figure 6. The accreditation steering committee would select a maximum of five to six indicators for each student outcome. The advantage of this approach is that data will be collected by the instructors during the courses regular pedagogical activities.

We illustrate the idea using ABET's outcome (a) which states that 'An ability to apply knowledge of computing and mathematics appropriate to the programme 's student outcomes and to the discipline.' For this specific outcome, we select the following five indicators from the various indicated courses in the programme. That is:

(1) Students shall demonstrate the ability to analyse and interpret statistical data (*Probability and Statistics*);
(2) Students shall be able to apply fundamental concepts of discrete mathematics, such as logic, Boolean algebra, proofs, set theory, relations, functions, and combinatorial mathematics (*Logic Design* or *Computer Organisation*);
(3) Students will acquire familiarity with basic classes and properties of formal languages. In particular, they will be able to determine whether a formal language is regular, context-free, recursive, or recursively enumerable (*Algorithms* or *Automata Theory*);
(4) Students should be able to mathematically deduce and find a closed-form for simple recurrence relations (*Algorithms*);
(5) Students will be able to understand and use basic graph theoretic algorithms and terminologies (*Algorithms*).

Courses are next aligned to student outcomes through a course map that establishes a relationship between the student outcomes and the performance criteria. This process is facilitated using an outcome-fulfilment form (Table 1).

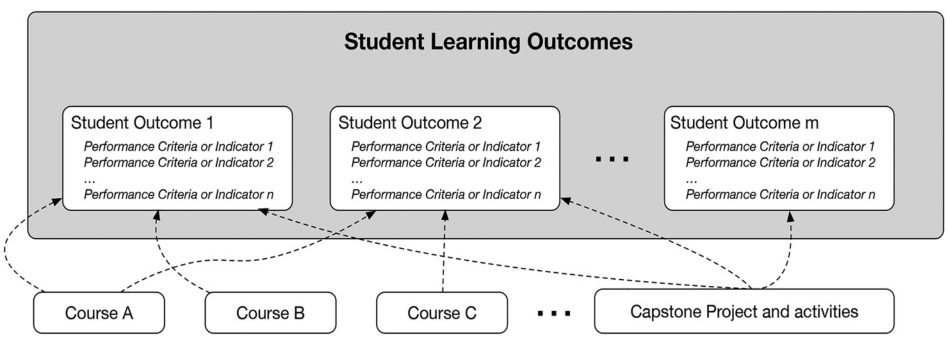


Figure 6. Skills and knowledge that feed into performance criteria through course learning outcomes.

4.1.5. Curriculum mapping.

The curriculum map is a visual representation of students' curricular progression as it relates to shared expectations among faculty in the programme. The map is represented using a matrix that labels intersections between the courses and the learning opportunities on one dimension and the student outcomes on the other. The curriculum map helps in ensuring that students have the opportunity to achieve the student outcomes in addition to identifying gaps and redundancies in the curriculum. The course maps (Table 1) are aggregated in order to develop a programme curricular map that identifies courses in the curriculum where the student outcomes are enabled at different learning levels.

We develop our curriculum map using performance criteria as the fine-grained mapping provides more opportunities for identifying curricular weaknesses, strengths, and areas of improvement. In addition to the courses, we list all co-curricular programmes and activities in the programme where students may acquire the necessary learning. A cell in the map indicates the relationship between the courses and learning opportunities, on the one hand, and the student outcomes on the other. This is accomplished using a labelling system of I (introduced), R (reinforced), and E (emphasized) as follows (Maki 2012):

- *Introduction level* indicates that students are not expected to be familiar with the content or skill at the collegiate level. Thus, learning activities focus on basic knowledge, skills, and competencies at an entry-level of complexity.
- *Reinforcement level* indicates that students are expected to possess a basic level of knowledge and familiarity with the content or skills at the collegiate level. Typically, instruction focuses on learning activities that enhance and strengthen knowledge, skills, and on expanding complexity.
- *Emphasis level* indicates that students are expected to possess a strong and advanced foundation in the knowledge, skill, or competency at the collegiate level. The programme is typically assessed and data are collected at this level as the instructional and learning activities focus on the use of the content or skills in multiple contexts and at multiple levels of complexity.

Table 1. Example course outcome fulfilment for a Computer Organisation course. A course outcome **I**ntroduces, **R**einforces, or **E**mphasizes a specific student outcome.

	Course learning outcomes
1	Understand the internal organisation of a computer system through an assembly language
2	Design, implement, and simulate the data path and the control unit of a simple computer based on an ISA
3	Understand pipelining including instruction sequencing, register value forwarding, and data interlocking
4	Understand the basic concepts of multiprocessor and multi-core designs
5	Understand the history and possible future of the field necessary for staying at the forefront

1	2	3	4	5	Student Outcomes
					An ability to apply knowledge of computing and mathematics appropriate to the programme's student outcomes and to the discipline
	I				An ability to analyse a problem, and identify and define the computing requirements appropriate to its solution
	E				An ability to design, implement, and evaluate a computer-based system, process, component, or programme to meet desired needs
	I				An ability to function effectively on teams to accomplish a common goal.
				I	An understanding of professional, ethical, legal, security, and social issues and responsibilities
	I				An ability to communicate effectively with a range of audiences.
				I I	An ability to analyse the local and global impact of computing on individuals, organisations, and society.
	R			R	Recognition of the need for and an ability to engage in continuing professional development
	R				An ability to use current techniques, skills, and tools necessary for computing practice.
		I	I		An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modelling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices
	I				An ability to apply design and development principles in the construction of software systems of varying complexity.

4.1.6. Assessment schedule.

Once the curriculum map has been finalised, an assessment schedule is determined based on courses and learning opportunities where students are expected to possess strong and advanced foundation in the knowledge, skill, or competency. The assessment schedule, as shown in Figure 7, includes:

(1) The student outcome or indicator that is to be measured;
(2) The courses from which data will be collected;
(3) The assessment instruments that will be used;
(4) The performance standard or the threshold that the students must meet so that the outcome or the indicator is considered met;
(5) The faculty who will collect the data;
(6) The semester, relative to the cycle year, when data are to be collected. For example, in the partial plan shown in Figure 7, data will be collected for student outcome 1 (SO.1) in the first year of the assessment cycle where the length of the cycle is determined by the steering committee.

The assessment schedule is communicated early in the semester to the concerned faculty or collection agent. Data are collected from the relevant performance criterion using the appropriate instruments, and reported through an online system or through a standard and simple form that documents the process. One such a form that is widely used is the *Faculty Course Assessment Report (FCAR)*, first introduced by Estell (2004). The FCAR includes a header, grades distribution, student outcome assessment, possible student feedback, and proposed actions for improvement. The FCAR can be easily developed as an online form and used for the collection of assessment data in order to draw conclusions regarding continuous improvement (Table 2). The effective use of the FCAR should lead to a more consistent standard of teaching, learning, and assessment.

4.1.7. Evaluation and closing the loop.

Contrary to the *academic* belief system, assessment of student learning is not about data collection but rather about understanding how the programme works and whether it contributes to student development. Therefore, assessing and evaluating the extent to which the student outcomes are

Performance Criteria	Strategies	Assessment Method(s)	Source of Assessment	Performance Standard	Collection Agent
PC1: Students shall demonstrate the ability to analyze and interpret statistical data;	MTH 305 CSC 599	Embedded assessment. Exit Survey.	MTH 305 CSC 599	67% or above. ≥ Good ≥ Good	S. Abi Ghanem C. Nour Assessment Officer
PC2: Students shall be able to apply fundamental concepts of discrete mathematics (*Logic, Boolean algebra, proofs, set theory, relations, and functions*) in order to model computational problems;	CSC 320, CSC 322, MTH 207, CSC 599	Embedded assessment. Exit Survey.	CSC 322 MTH 207 CSC 599	67% or equiv. ≥ Good ≥ Good	H. Harmanani S. Sharafeddine Assessment Officer
PC3: Students will acquire familiarity with basic classes and properties of formal languages. In particular they will be able to determine whether a formal language is regular, context-free, recursive, or recursively enumerable.	CSC 310, MTH 207, CSC 599	Embedded assessment. Exit Survey Locally Developed Exam	MTH 307 CSC 599	67% or equiv. ≥ Good ≥ Good 70% or above	C. Nour F. Abu Khzam Assessment Officer
PC4: Students should be able to mathematically deduce and find a closed-form for simple recurrence relations.	CSC 243, CSC 245, CSC 310, MTH 201, MTH 307, CSC 599	Embedded assessment. Exit Survey Locally Developed Exam	MTH 307 CSC 310 CSC 599	65% or equiv. ≥ Good ≥ Good 70% or above	C. Nour F. Abu Khzam Assessment Officer
PC5: Students will be able to understand and use basic graph theoretic algorithms and terminologies.	CSC 245, CSC 310 MTH 307, CSC 599	Embedded assessment. Exit Survey Locally Developed Exam	CSC 310 MTH 307 CSC 599	67% or equiv. ≥ Good ≥ Good 70% or above	C. Nour F. Abu Khzam Assessment Officer

Figure 7. Example assessment plan and schedule for Student Outcome 1 (SO.1).

Table 2. Assessment part of the Faculty Course Assessment Report (FCAR).

Course Outcome or Performance Criterion:
Related Student Outcome:

Assessment Method	Average	Percent meeting performance standard	Performance standard used

being attained is a very important step in ABET accreditation. Furthermore, 'the results of these evaluations must be systematically utilized as input for the continuous improvement of the programme ' (ABET 2016) as well as 'evidence of actions taken to improve the programme'. The evaluation process should be documented and reported for the purpose of ABET accreditation.

The evaluation must be based on predefined thresholds; thus, every performance criterion is evaluated based on the four-level metric given in Table 3. A performance criterion is deemed to be met if 70% of the students achieve it with a score of at least 75% in the case of embedded assessment or a score of 3 or above in the case of scoring rubrics based on a 1–4 scale. The threshold can vary across the assessment instruments and maybe adjusted over the assessment cycle. For example, indirect assessment instruments should have higher thresholds than direct assessment instruments.

An outcome is deemed to be met based on the results of its performance criteria. However, performance criteria for a specific student outcome are met to a varying degree; while some may exceed expectations others may fall below expectations. One approach that we propose is to aggregate the results of the performance criteria by assigning the student outcome a cumulative score average that is computed in a similar way to a student's GPA. Thus, each performance criterion is assigned a score from 1 to 4 as given in Table 3 based on the percentage of students who achieve the criterion. If one assumes that there are n equally important performance criteria per student outcome, then that outcome is deemed to be met if it has a cumulative score average of 3 or above. However, it is also possible to give more importance to specific performance criteria using weights. An outcome will be then deemed to be met based on the following aggregation rule $R(V) = (1/n) \sum_{i=1}^{n} w_i PC_i$ where w_i is the performance criterion's weight and PC_i is the performance criterion score based on Table 3. Performance criteria that are *not met* or that are *minimally met* are scrutinised, and improvements actions are recommended in order to narrow the gaps identified between learning activities and actual outcomes.

The proposed actions may include adjustments to the programme or the programme 's operations (including budgetary) which are either being proposed or have already been made. Other adjustments may include the modification of the courses contents, the addition or deletion of courses, and the acquisition of equipment or facilities. One of the challenges during this phase is the ability to prioritise the proposed improvements and to find the proper balance between programme needs and financial and academic constraints. A final recommendation will be made to the department.

Although the cycle for assessment and evaluation of achievement of the student outcomes is three years, if major issues are identified, appropriate action is taken on a shorter time scale. Finally, it should be noted that programme objectives are not required to be assessed but simply reviewed in every cycle in order to ensure that they meet the needs of the programme 's constituencies.

5. Assessment results reporting and visualisation

ABET requires the programme to provide 'evidence of the assessment, evaluation, and attainment of student outcomes for each programme'. Accordingly, the programme is expected to gather and make available the assessment materials that will assist the review team in its evaluation.

A good and effective way of reporting the assessment results is through an outcomes book that describes the assessment and evaluation process for each outcome. The report should include the assessed outcome and its performance indicators or criteria, the instruments used, the assessment

Table 3. Evaluation of student outcomes or performance criteria based on a four-level metric.

Percent of students achieving $\geq$ 70%	Criterion classification	Criterion score
$\leq$ 64%	Below expectations	1
65–74 %	Minimally meet expectations	2
75–89 %	Meet expectations	3
90–100 %	Exceed expectations	4

results and their interpretations, and the proposed improvements. The assessment report should be succinct and simple as the reviewers would not be willing to wade through complex charts and reports in order to find the evidence that they seek.

Although tabular representations and histograms are most commonly used for representing the assessment results, they are not always indicative and meaningful. A well-designed visual representation can replace cognitive calculations with simple perceptual inferences and improve comprehension, memory, and decision-making (Heer, Bostock, and Ogievetsky 2010). In what follows, we illustrate a visual approach for reporting assessment results using the data that was used for the assessment of a computer science programme at our university. The programme implemented the described outcome-based assessment process by integrating the assessment process at the course and at the programme levels, and was successfully accredited by ABET in two years.

5.1. Data visualisation

Data visualisation involves the use of graphical aid in order to discover a message that is buried in data. Visualisation is combined with infographics in order to convey the known message. In other words, data visualisation can be published as an infographic. A graphical visualisation approach provides a more intuitive mechanism for representing, analysing, and understanding the assessment data. For the purpose of assessment visualisation, we propose the use of *interactive* and *dynamic data visualisations* so that as the assessment results change, the data visualisation updates automatically. There are various tools that can be used for this purpose such as Microsoft Excel and Apple Numbers which are readily available on most computers. A more powerful business intelligence tool that can be used for visualisation as well as data analysis and reporting is Tableau Software (2016) which is available for free for academic teaching. Finally, there are various free tools (University of Maryland 2016) and open source tools such as Google Fusion Tables that allows users to store, share, query, and visualise data tables (Google 2016a), and Google Charts that allows the use of interactive charts for browsers and mobile devices (Google 2016b). We use a combination of the above in order to develop visual assessment reports.

5.2. Assessment visualisation zoo

The space of possible visualisation designs is extremely large as there is usually a number of visual encodings that correspond to a given data set. Heer, Bostock, and Ogievetsky (2010) provide a

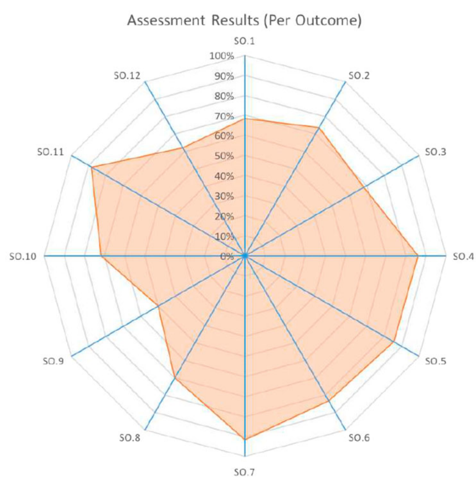
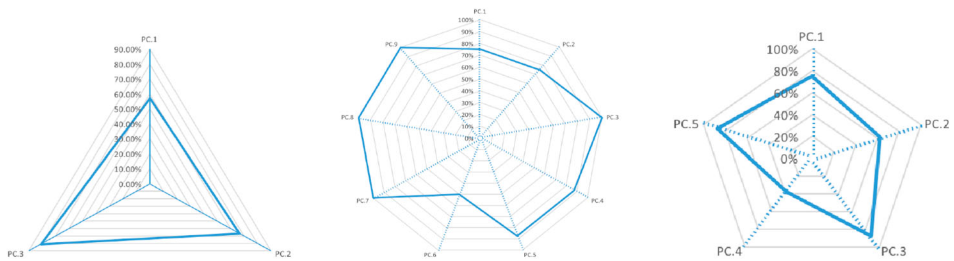


Figure 8. Assessment results for all programme outcomes using a radar chart.

tour through what they coin as the 'visualisation zoo', showcasing various visual encodings techniques. We have used the following for the purpose of assessment visualisation:

(1) *Radar or Star Chart*: Assessment results for all outcomes or for the KPIs can be visualised in one single graph using Microsoft Excel. Figures 8 and 9 illustrate our assessment results using a radar graph. The graph consists of 12 equiangular spokes with each spoke representing an outcome. A line is drawn connecting the data values for each outcome. The radar or star chart can be used to easily examine the relative values for a single outcome in addition to locating similar or dissimilar assessment results. Most importantly, the star plot can be used to identify any possible outliers in the assessment process. For example, the results of outcomes 7 and 11 in Figure 8 are outliers while outcomes 9 and 12 are clearly not met.

(2) *Treemap* : Treemaps are effective visualisation tools for hierarchical structures and are extremely effective in showing attributes using *size* and *colour* coding (Johnson and Shneiderman 1991). Treemaps display the assessment data hierarchically using a set of nested rectangles. Each outcome corresponds to a branch of the tree and is given a rectangle, which is then tiled with smaller rectangles representing performance criteria or sub-branches. The outcomes areas are proportional to the specified assessment data dimension for that outcome, and are coloured to show a separate dimension of the data. In the case of assessment visualisation, *Treemaps*



(a) Student Outcome 3 (b) Student Outcome 4 (c) Student Outcome 8

Figure 9. Assessment results for various student outcomes per performance criteria using a radar chart. (a) Student outcome 3, (b) student outcome 4, and (c) student outcome 8.

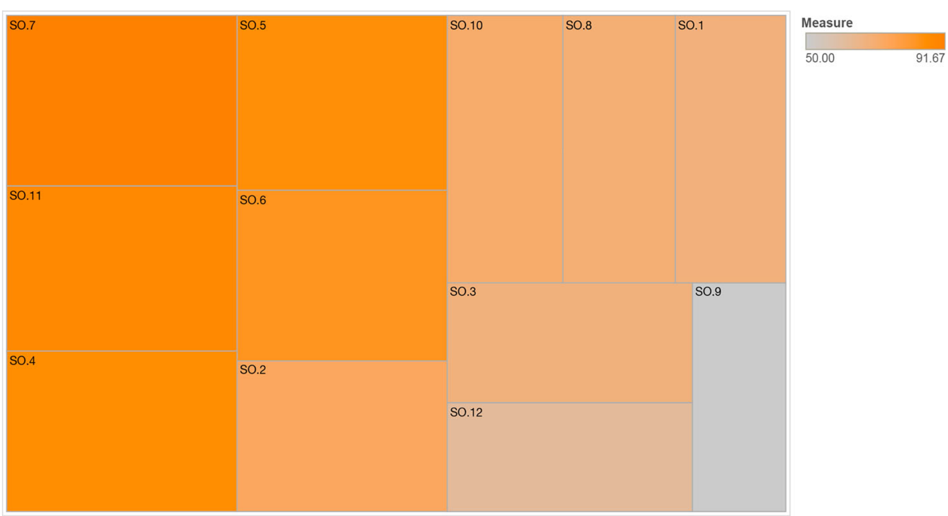


Figure 10. Assessment results for all programme outcomes using a Treemap.

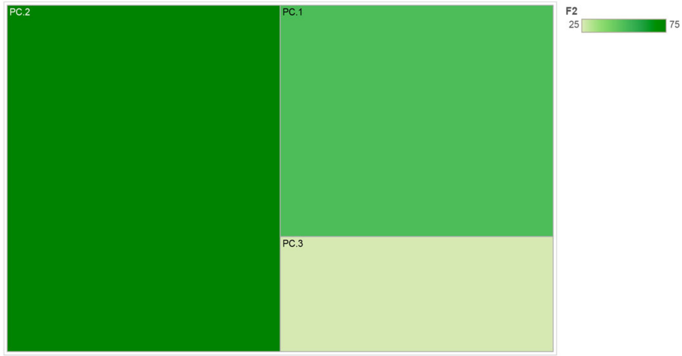


Figure 11. Assessment results for student outcome 9 per performance criteria using a Treemap.

can enable users to compare the sizes of rectangles (outcomes) and of sub-trees (performance criteria), and are especially strong in spotting unusual patterns. For example, Figure 10 shows a Treemap visualisation using Tableau examining all outcomes (rectangles) and achievement (colour). The outcomes that are highly achieved and exceed expectations are highlighted in dark orange (91.67%) while the outcomes that are not achieved are highlighted in grey (50%). The colours in between correspond to outcomes that are achieved at various levels. The size of the rectangle or outcome corresponds to the assessment data dimension for that outcome. Any outcome maybe queried by clicking on it. For example, clicking on outcome 9 would display the information regarding that outcome, and a new *Treemap visualisation* for the performance criteria of that outcome as shown in Figure 11.

(3) *Packed bubble charts* : Bubble charts can be used to visualize assessment data without regards to axes. The bubbles are packed in as tightly as possible to make efficient use of space. Figure 12 shows the assessment results for all programme outcomes using a packed bubble chart. The arrangement of the bubbles is random, but the size of the bubbles represent the measured outcome. Simply put, larger bubbles equal larger values.

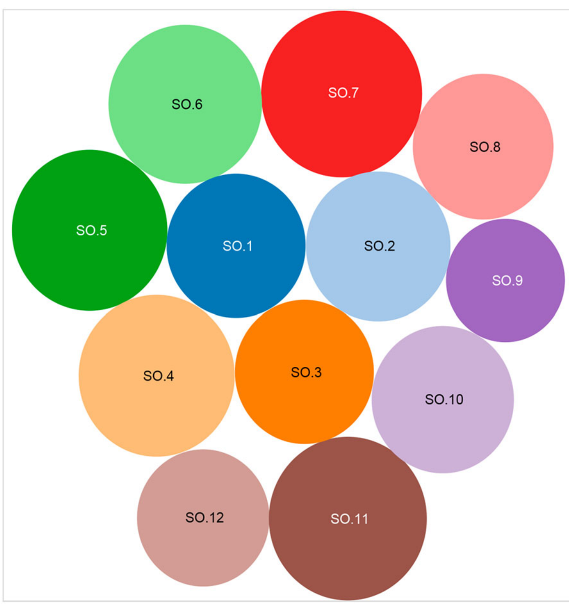


Figure 12. Assessment results for all programme outcomes using a packed bubble chart.

(4) *Bubble chart* : The bubble chart can be used to visualize assessment data longitudinally over multiple years, all in one elegant and easy to interpret chart. The bubble chart communicates two dimensions of data: a numerical value visualized in the scale of its circular bubbles, and what each bubble represents.
(5) *Dashboards infographics* : Infographics combine graphics and text in order to convey a message. We use a set of dashboard assessment indicators that can give a snapshot of progress towards achieving the outcomes. Dashboards can also be used to report key measures of students success in addition to admission and acceptance information.

6. Conclusion

This paper presented a systematic approach for outcome-based assessment that facilitates faculty participation while simplifying the assessment and reporting processes through effective and meaningful *visualisation*. The process is based on a bottom-up approach that minimizes faculty's effort and increases faculty buy-in. The proposed approach has been implemented and used for the successful ABET accreditation of a computer science programme, and can be easily adapted to any higher education programme.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributor

Haidar Harmanani received the B.S., M.S., and PhD degrees all in Computer Engineering from Case Western Reserve University, Cleveland, OH, USA, in 1989, 1991 and 1994, respectively. He joined the Lebanese American University, Byblos, Lebanon, in 1994 as an Assistant Professor of Computer Science. Currently, he is a Professor of Computer at LAU, Byblos. Prof. Harmanani has been on the programme committee of various international conferences including the IEEE NEWCAS Conference, the IEEE Midwest Symposium on Circuits and Systems, the IEEE International Conference on Electronics, Circuits, and Systems, the 14th IEEE International Conference on Microelectronics, and the IEEE Design Automation and Test in Europe. His research interests include electronic design automation, high-level synthesis, design for testability, and cluster parallel programming. He is a senior member of IEEE and a senior member of ACM.

ORCiD

Haidar M. Harmanani http://orcid.org/0000-0001-5416-4383

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