Quantitative Approach to Measuring Course Learning Outcomes

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Abstract

Accreditation criteria of computing and engineering programs require effective learning outcomes assessment with documented procedures, tools, results, and actions to close the assessment loop with broad faculty involvement. This paper describes a methodology for providing quantitative measurement of a course learning outcomes. The methodology uses a linkage matrix that associate each course learning outcome to one or more course assessment tool. The approach adopted provides a numeric score between 0 and 1 for each learning outcome with respect to each assessment tool and a combined score will be calculated for each learning outcome from the tools associated with that outcome. The proposed methodology also provides insights into the consistency of the various assessment tool used to measure the achievement of a particular course learning outcome. The methodology described here has been successfully adopted in obtaining accreditation to for various computing degree programs offered by the College of Information Technology at Ajman University of Science & Technology.

Keywords: ***Course outcomes; Course assessment; learning outcomes; Accreditation..***

Introduction

Academic programs assessment and evaluation is becoming an important process in providing improved education to students through modified curriculum and instruction. Each of the programs offered by the College of Information Technology at Ajman University of Science & Technology (AUST) is accredited by the Commission for Academic Accreditation (CAA) of the Ministry of Higher Education and Scientific Research which implements standards and procedures similar to those of the Accreditation Board for Engineering and Technology (ABET) that requires an academic program to provide an evaluation of program quality and effectiveness as part of a self-study report. Assessment has also become a tool of accountability in education by providing evidence on how effective the teaching is [1]. An assessment plan will determine how well students are benefiting from a learning experience offered by a program of study. Assessment activity at AUST started in 2001 with two online forms to be filled by students: The Student Course Evaluation Form and The Academic Advisory Evaluation Form. The first form collects students' feedback with regard to each course taken during the semester. The questions asked relate to four aspects of teaching a course. The first is concerned with the background to the course, textbooks, and laboratory work. The second set of questions is intended to evaluate the performance of the instructor from a

student's point of view. The third and fourth group of questions relate to examinations and information resources respectively. The second form contains a set of questions that evaluate the performance of the academic advisor again from a student's point of view. These evaluations are considered in the annual evaluation of a faculty member and were found to be very useful in identifying persistent problems with regards to a specific course or a particular instructor.

The next major advancement in assessment at AUST occurred in second semester of 2004/2005 when the department of Computer Science established procedures and tools for assessing and evaluating the learning outcomes of the Computer Science program as part of a pilot study conducted by AUST in order to establish well-defined procedures and tools for assessing the effectiveness of all programs offered by the University. These procedures and tools were approved by the Ministry of Higher Education & Scientific Research in the United Arab Emirates and were subsequently used to obtain successfully accreditation for all AUST programs at the undergraduate and post graduate levels.

In September 2005 and in recognition of the importance of the assessment of all aspects of a university life, AUST has established the Quality Assurance and Institutional Research Unit (QAIRU). This unit has the responsibility of providing assistance to service departments, colleges and other units of AUST

in establishing their procedures for measuring their objectives and learning outcomes at different levels. The QAIRU also acts as the central repository of assessment information conducted at the University. QAIRU uses this centralized reporting function to develop and submit the annual Institutional Effectiveness Report to the Commission for Academic Accreditation (CAA) of the Ministry of Higher Education and Scientific Research.

Literature REVIEW

Thomas A. Angelo [2] stated that *"Assessment is an ongoing process aimed at understanding and improving student learning. It involves making our expectations explicit and public; setting appropriate criteria and high standards for learning quality; systematically gathering, analyzing, and interpreting evidence to determine how well performance matches those expectations and standards; and using the resulting information to document, explain, and improve performance. When it is embedded effectively within larger institutional systems, assessment can help us focus our collective attention, examine our assumptions, and create a shared academic culture dedicated to assuring and improving the quality of higher education".*

In the last few years, learning outcomes have achieved a wide spread importance in conferences and literature as a model of assessing the knowledge and skills obtained from a learning experience. Learning outcomes have

applications at three distinct levels: (i) the local level of the individual higher education institution for course units/modules, programs of study and qualifications; (ii) the national level for qualifications frameworks and quality assurance systems; and (iii) internationally (for wider recognition and transparency purposes [3]. Learning outcomes focus on measurable cognitive, behavioral and attitudinal development of students as they interact with a learning activity. They are what students are expected to demonstrate in terms of knowledge, skills, and attitudes upon completion of a learning experience [3, 4].

Learning outcomes and outcomes-based approaches have implications for curriculum design, teaching, learning and assessment, as well as quality assurance. They are likely to form an important part of the twenty-first century approaches to higher education and the reconsideration of such vital questions as to what, who, how, where and when we teach and assess [3]. In terms of curriculum design and development, learning outcomes are at the forefront of educational change. They represent a change in emphasis from teaching to learning that characterize what is known as the adoption of a student-centered approach in contrast to traditional teacher-centered viewpoint. Student-centered learning produces a focus on the teaching-learning-assessment relationship and the fundamental links between the design, delivery and measurement of learning [3].

To implement the learning outcomes approach, a program must first formulate program educational objectives (broad goals) that address institutional and program mission statements and are responsive to the expressed interests of various groups of program stakeholders. The program must then formulate a set of program learning outcomes (knowledge, skills, and attitudes the program graduates should have) that directly address the educational objectives and encompass certain specified outcomes that are related to the particular program being assessed and in many cases specified by appropriate bodies as in the case of ABET for engineering and information technology programs for example. The program educational objectives and outcomes must be specified in a self-study report. The next step is to formulate a set of measurable learning outcomes for each course in the curriculum. Based on these courses learning outcomes, a mapping is constructed between the program learning outcomes and courses learning outcomes. This mapping will be used as a part of a process to provide a quantitative measurement of the attainment of program learning outcomes based on the degree to which courses learning outcomes have been achieved according to a specified criteria.

Program learning outcomes are also assessed by using other indirect assessment tools such as alumni survey forms, exist survey forms, employers survey forms, and internships [4]. However, course learning outcomes are

crucial to the process; among other things, they enable the program to demonstrate precisely how specific program learning outcomes are addressed in the curriculum. If course learning outcomes are then assessed continuously and the results are used to improve instruction that address them, the degree to which the program meets its self-selected goals must inevitably improve. The contribution of this paper is to describe a methodology that can be used to provide a quantitative measurement of the attainment of each course learning outcome.

FORMULATING COURSE LEARNING OUTCOMES

Once the program goals and program learning outcomes have been articulated and the curriculum designed, measurable course learning outcomes must be developed for each course in the curricula. Each course learning outcome must map to at least one program learning outcome to ensure that all courses in the program of study are addressing the overall program learning outcomes. This process also verifies whether each program learning outcome is addressed in at least one course [5, 6]. Designing courses using learning outcomes leads to a more student-centred approach: it emphasizes a shift from what staff members teach towards what the student is able to do on successful completion of the course. Specifically, learning outcomes can help staff to focus on exactly what they want students to achieve in terms of both knowledge and

skills; inform students of what is expected of them and help concentrate their efforts; and provide a useful guide to stakeholders about the general knowledge and understanding that a graduate will posses [3, 5].

A well-structured course should show clear alignment between the learning outcomes and the assessment criteria used on the course; in turn this leads to the design of appropriate assessment tasks, and to deliver the course in a way which enables students to reach the required outcomes. Biggs [7], has developed the fundamental idea of constructive alignment, which is the process of synchronizing teaching methods, learning activities, and assessment tasks with course's learning outcomes. Alignment of each of these three elements with learning outcomes is crucial for effective teaching [7, 8]. Teaching activities should be driven by course learning outcomes and should support students in their learning activities and prepare them for assessment [7, 8]. This alignment between learning outcome, learning and teaching methods, assessment tasks and assessment criteria makes the whole process transparent to the students and to other interested stakeholders.

Course learning outcomes should specify the minimum acceptable (threshold level) standard for a student to be able to pass a course. This means that it is important to express learning outcomes in terms of the essential learning for a module or course, so a small number of learning outcomes which

are of central importance should be developed and not a large number of superficial outcomes. Learning outcomes should be written using action verbs so that students are able to demonstrate that they have learned or achieved the outcome [9].

Category	Description
Knowledge	recalling or remembering something without necessarily understanding, using, or changing it
Comprehension	understanding something that has been communicated without necessarily relating it to anything else
Application	using a general concept to solve problems in a particular situation; using learned material in new and concrete situations
Analysis	breaking something down into its parts; may focus on identification of parts or analysis of relationships between parts, or recognition of organizational principles
Synthesis	creating something new by putting parts of different ideas together to make a whole.
Evaluation	judging the value of material or methods as they might be applied in a particular situation; judging with the use of definite criteria

Table 1. Bloom's cognitive levels.

In 1956, Benjamin Bloom headed a group of educational psychologists who identified three domains of educational activities [10]. These are: cognitive, affective, and psychomotor. Knowledge, understanding and intellectual skills fall under the cognitive domain. The affective domain refers to attitudes and the psychomotor domain covers manual and physical skills. The group further divided the cognitive domain into six levels that describe the learning process from the simplest to the most complex. These levels are: knowledge, comprehension, application, analysis, synthesis and evaluation. The first two of

these relate specifically to knowledge and understanding, while the remaining four involve intellectual skills. While it might seem appropriate to concentrate on the lower two categories for lower level courses, it is recommend that students should be engaged in higher level activities on a smaller, more focused scale, from the outset [11]. Bloom's levels of cognitive skills are shown in Table 1 along with a description of each skill.

The following is a list of verbs for use when creating student learning outcome statements [11]:

1. To measure ***knowledge*** (common terms, facts, principles, procedures), ask these kinds of questions: Define, Describe, Identify, Label, List, Match, Name, Outline, Reproduce, Select, State. Example: "*List the steps involved in building an information system*."
2. To measure ***comprehension*** (understanding of facts and principles, interpretation of material), ask these kinds of questions: Convert, Defend, Distinguish, Estimate, Explain, Extend, Generalize, Give examples, Infer, Predict, Summarize. Example: "*Summarize the basic principles of software design."*
3. To measure ***application*** (solving problems, applying concepts and principles to new situations), ask these kinds of questions: Demonstrate, Modify, Operate, Prepare, Produce, Relate, Show, Calculate, Solve, Use. Example: " Calculate *the cost of the shortest path from node A to node B in the following graph*:"
4. To measure ***analysis*** (recognition of unstated assumptions or logical fallacies, ability to distinguish between facts and inferences), ask these kinds of questions: Diagram, Differentiate, Distinguish, Illustrate, Infer, Point out, Relate, Select, Separate, Subdivide. Example: "*Analyze the requirements of a school information system*."
5. To measure ***synthesis*** (integrate learning from different areas or solve problems by creative thinking), ask these kinds of questions: Categorize, Combine, Compile, Devise, Design, Explain, Generate, Organize, Plan,

Rearrange, Reconstruct, Revise, Tell. Example: "*Design a data flow diagram for the following software requirements specification*:"

6. To measure ***evaluation*** (judging and assessing), ask these kinds of questions: Appraise, Compare, Conclude, Contrast, Criticize, Describe, Discriminate, Explain, Justify, Interpret, Support. Example: "*Contrast object oriented software design with structured software design.*"

The following are assembled guideline from various sources [1, 5, 6, 8] as well as the authors' experience in writing course learning outcomes:

1. Action verbs from Bloom's Taxonomy with an emphasis on higher-order thinking skills should be used.
2. To facilitate the assessing of outcomes, one verb per learning outcome should be used.
3. There should be between 4-8 learning outcomes for each course, in fact the fewer the better.
4. Course learning outcomes should describe what a student should be able to DO at the end of a course rather than what the instructor teaches.
5. Course learning outcomes should be written in language that students (and those outside the field) are able to understand.
6. Course learning outcomes are typically not content-specific.
7. Ideally, each course or program should include learning outcomes from more than one domain (cognitive, psychomotor, and affective).
8. Each course learning outcome should be measurable and can be assessed, preferably using more than one assessment tool.
9. Weak verbs such as "be aware", "appreciate", "identify", "read", and "recognize", are to be avoided in general. For example, recognizing a phenomenon is weak compared to understanding that phenomena.
10. Earlier courses in a program may have outcomes where students "*explain*", *"describe*", and understand", advanced courses should provide more analytical skills where students can "*analyze*", "*design*", "*implement*", and "*build"* as examples.

The following is an example of a bad learning outcome: "*Develop skills to analyze a large volume of data*". Obviously students should acquire these skills

during the course and not develop them after finishing the course because that will defeat the whole objectives of creating course learning outcomes. The following is an example of course learning outcomes written for *Algorithms and Problem Solving* course of the *Information Technology* program offered by the College of Information Technology at Ajman University of Science and Technology. After completing this course, students will be able to:

1. *Explain the problem-solving process used to construct a computer program.*
2. *Construct an algorithm using pseudo code.*
3. *Select a suitable name, data type, and initial value for a variable or constant.*
4. *Create code using selection control statements.*
5. *Create code using repetition control statements.*
6. *Manipulate data using arrays, strings and records.*
7. *Use files for input and output processing.*
8. *Construct and test a user defined function.*

COURSE ASSESSMENT METHODS

Assessment is usually classified into summative and formative for the purpose of considering different objectives of course assessment methods [7, 8, 12]. Summative assessment refers to the assessment of the learning and summarizes the achievements of learners at a particular point in time. After a period of work, the learner sits for a test and then the teacher marks the test and assigns a score. The test aims to summarize learning up to that point. Midterm and end of course exams falls into this category. In an educational setting,

summative assessments are typically used for evaluation purposes to assign students a course grade. Formative assessment is generally carried out throughout a course or project. Formative assessment, also referred to as "educative assessment," is used to aid learning. In an educational setting, formative assessment might be a teacher, peer, or the learner, providing feedback on a student's work, and would not necessarily be used for grading purposes. Formative assessments are diagnostic. Robert Stake [13] who is an educational researcher provided the following interesting analogy: *When the cook tastes the soup, that's formative. When the guests taste the soup, that's summative*

Summative and formative assessments are often referred to in a learning context as *assessment of learning* and *assessment for learning* respectively [14]. Assessment of learning is generally summative in nature and intended to measure learning outcomes and report those outcomes to students, parents, and administrators. Assessment for learning is generally formative in nature and is used by teachers to consider approaches to teaching and next steps for individual learners and the class [14, 15].

In general, high-quality assessments are considered those with a high level of *reliability* and *validity* [14, 15]. Reliability relates to the consistency of an assessment method. A reliable assessment is one which consistently achieves the same results with the same or similar group of students. Reliability is

affected by factors such as ambiguous questions, too many options within a question paper, vague marking instructions and poorly trained markers. A valid assessment is one which measures what it is intended to measure. An exam is valid when it properly assesses the syllabus upon which the examination is based. A common form of formative assessment is *diagnostic assessment*. Diagnostic assessment measures a student's current knowledge and skills for the purpose of identifying a suitable program of learning. *Self-assessment* is a form of diagnostic assessment which involves students assessing themselves [15].

Assessment methods should be designed such that they are able to measure the full range of outcomes associated with a particular course. For example, for information technology and engineering courses, they should include [1]:

- assessment methods that measure the ability of students in demonstrating subject knowledge,
- designing and conducting experiments,
- gathering data, analyzing and interpreting data,
- demonstrating and applying knowledge,
- defining a technical problem,
- planning a project,
- conducting a review of the literature,
- generating ideas and creativity,
- perform preliminary and detailed design,
- functioning effectively and as a member of a team,
- solving technical problems,

- defining computing requirements to solve a particular problem,
- formulating and analyzing engineering/technical/ computing problems,
- solving engineering/technical/computing problems,
- understanding and demonstration of ethical issues and professional responsibilities,
- understanding and demonstration of social responsibilities,
- written and oral communications,
- making effective use of library and on-line resources, and
- awareness of contemporary issues in industry.

Current assessment tools used to assess courses learning outcomes in the College of Information Technology at Ajman University of Science and Technology include: *Mid Term Exam, Final Written Exam, Short Paper, Team Project, Oral Discussions, Lab work, Presentations, Seminars, Reports, Tests & Quizzes, Student Portfolio, and Individualized Products.*

MEASURING COURSE LEARNING OUTCOMES

The next step is to provide a data-backed quantitative measurement of how well students are achieving each course's learning outcomes. The process used to get these measurement should be easy to implement and not time consuming to instructors. It is not acceptable to determine a student's achievements of course learning outcomes on the basis of the final grade obtained in the course alone. These grades represent the aggregation of too many factors, causing the student's ability in any particular topic area within the course to be lost in the aggregation [16]. A more detailed level of analysis is

needed. One approach that we suggest in this paper is to create a linkage matrix that associate each course learning outcome with one or more assessment tool. Listed in section III. This matrix is shown in Figure 1.

The measurement criteria is as follows: for each course outcome *I* and assessment tool *J* that address an outcome *I*, the *maximum grade* allocated for outcome *I* and the *average scored grade* obtained by students for outcome *I* is entered . An outcome *I* is achieved if the ratio *total_scored/total_max* is >=0.70 where, *total_scored* is the sum of average grades obtained by students from all tools *J* for outcome *I*, and *total_max* is the sum of the maximum grade of all tools used to measure outcome *I*.

This approach of measuring the achievement of a particular course learning outcome can provide two very important observations. First, it will indicate which course learning outcome the students have failed to achieve and consequently, what remedial actions should be contemplated to rectify the situation. Secondly, this measurement technique will also indicate if a learning outcome has been achieved consistently by all assessment tools assigned to it which further provide an insight into the consistency of the various assessment tool in measuring a particular course learning outcome. For the purpose of making a decision at the program outcomes level, it is assumed that the outcomes of the course as a whole are attained if 70% or more of the outcomes

have been achieved. However, the failed outcomes must be addressed and appropriate remedial actions taken as will be explained latter.

	Grade	Tool1	Tool2	Tool3	…	Toolw	Total	Ratio
Outcome #1	Scored				…			
	Max				…			
Outcome #2	Scored				…			
	Max				…			
…	Scored	…	…	…	…	…	…	…
	Max	…	…	…	…	…	…	
Outcome #n	Scored				…			
	Max				…			

Figure 1. Linking course outcomes to assessment tools.

The suggested methodology for providing a quantitative measurement of a course learning outcomes may impose a heavy burden on the instructors in terms of designing the questions for each assessment tool and data collection and analysis if implemented manually. However, we feel that an automated system will alleviate much of the burden on instructors' time and efforts. The assessment process described above has been successfully applied in obtaining accreditation and reaccreditation to all programs offered by the Information Technology College at Ajman University of Science & Technology.

CLOSING THE ASSESSMENT LOOP

Assessment of course learning outcomes is a continuous process and cyclical in nature. The assessment cycle as Implemented by the College of Information Technology at Ajman University of Science and Technology is depicted in Figure 2. The final steps in the assessment cycle are referred to as "closing the assessment loop" [17, 18]. Closing the loop refers to the process of

using the results obtained from various assessment activities to improve the program and to document such improvements with the intent to positively impact future student learning. In Figure 2, the shaded rectangles represent the steps required to close the assessment loop.

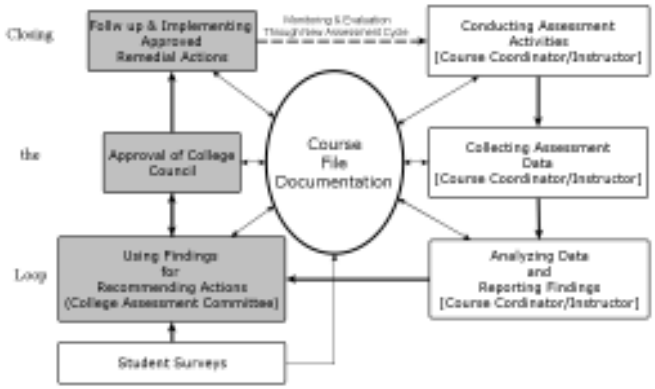

Figure 2. Closing the Assessment Loop.

After course instructors conduct assessment activities, collect assessment data and analyze it, the course coordinator will provide the quantitative measurement regarding the achievement of each course learning outcome as described in the table shown in Figure 1. This information will be reviewed by the College Assessment Committee. If necessary, the committee will consider a range of possible remedial actions as listed below. In addition, the College Assessment Committee will also take into consideration the results of students surveys which are conducted for each course towards the end of the semester. These surveys provide valuable information with regard to the suitability of textbook and references; academic background and prerequisite courses; course delivery modes; and lab activities among others. The College is also planning to

implement an indirect course assessment tool proposed by Yue [19]. In this approach, students taking a course complete a survey at the end of the semester to give a score from 1 to 5 on how well each course learning outcome is satisfied from their point of view. These results will influence the remedial actions to be considered by the committee.

Remedial actions can be anything from concluding that student performance with respect to a learning outcome meets expectations to major course change. The College of Information Technology at Ajman University of Science and Technology has articulated a set of remedial actions that might be considered by the College Assessment Committee if a course fails one or more of its learning outcomes. Currently, the assessment committee may choose one or more of the following remedial actions in order to address a particular failed learning outcome:

- Adding new knowledge units to a course.
- Refining or deleting certain course knowledge units.
- Changing prerequisite courses.
- Increasing the number of or changing the nature of course assignments.
- Changing textbook or course references.
- Changing course delivery methods.
- Providing support structures such as tutoring or help sessions.
- Refining or changing a failed learning outcome.
- Refining evaluation methods.
- Refining the implementation of the assessment process

- Refining criteria used in evaluation.
- Changing course instructor.
- Providing professional development to faculty in writing and assessing learning outcomes.
- Recommending additional research and evaluation if it was unclear what decisions should be made based on unclear evidence

The above list is continually updated as other remedial actions comes to light. The recommendations of the College Assessment Committee will be discussed by the College Council and approved remedial actions will be followed up and implemented. The effectiveness of these remedial actions will become apparent through the next assessment cycle of course learning outcomes. Every step of the assessment cycle is documented in the course file.

CONCLUSIONS

In this paper we have provided a description of the full assessment cycle for course learning outcomes and what remedial actions are needed to close the assessment loop. The main contribution of the paper is in proposing a methodology for providing a quantitative measurement of the level to which each course learning outcome has been achieved. In addition, this methodology provide valuable information regarding how each learning outcome is being assessed by the different assessment tools giving insights into the consistency of the various tools in measuring a particular course learning outcome. The approach described in this paper has been successfully applied as part of a wider

scheme to assess academic programs learning outcomes for the purpose of obtaining accreditation to all bachelor and postgraduate degree programs at AUST. Future work will investigate more appropriate techniques for assessing final year projects, internships, professional values. A more challenging task of computerizing the full process of assessing academic program learning outcomes is also planned for the near future.

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