AC 2011-2808: SOFTWARE-BASED ASSESSMENT METHOD FOR STUDENT LEARNING OUTCOMES AND PROGRAM OUTCOMES

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Software-based Assessment Method for Student Learning Outcomes and Program Outcomes

Abstract

Many articles have been published for course and program assessment in preparation for ABET/TAC evaluations. There is no single method to accomplish course and program assessment. In this paper, a detailed method is described to conduct such assessments by considering the contribution of each course assignment to the student learning outcomes for that course, and, in turn, the contribution of each course to the program outcomes. The method uses a software program to enter student grade data for each course semi-real-time during the semester. The instructor, based on the student scores, can choose to stress those topics in which the students perform weakly to assure that the student learning outcomes are achieved by the conclusion of the course. The method reveals strengths and weaknesses of the students based on assignment scores that are correlated to the achievement of student learning outcome for each course.

To utilize the method for the assessment of program level outcomes, the method must be adopted by the department or program and the entire faculty involved in teaching. Each faculty member completes information about assignments (assessment activities) and how those assignments relate to the student learning outcomes for the courses they are teaching. In addition, each faculty maps how the course learning outcomes are related to program outcomes. Then, the software automatically combines the data from all faculty to reveal strengths and weaknesses in the program learning outcomes. The results can then be utilized to close the loop in education, by incorporating the necessary modifications to the courses in the curriculum, and start a continuous improvement cycle. In this paper, the mapping process of linking assignments to student learning outcomes for each course, connecting each course outcome to the program outcomes, and further, combining the data to reveal strengths and weaknesses in the curriculum as they relate to achieving ABET/TAC criteria, are presented with examples.

Introduction

Course assessment, program assessment and implementation of a meaningful continual improvement program are some of the important elements that accreditation agencies such as ABET require that a program aspiring for accreditation or re-accreditation must demonstrate. Additionally, the accreditation agency also defines a detailed subdivision of a varied skill set that the graduates must have acquired by the time of graduation from a given engineering or technology program. As an example, such breakdown of the skill set in the case of ABET/TAC is recognized as the “a through k” criteria.

Typically, the engineering or technology program seeking accreditation compiles appropriate examples of students’ coursework from freshman to senior years and the text books used, arrange the documents along the skill subsets (a – k criteria), and presents them to the accreditation agency for evaluation. A presentation such as this for accreditation evaluation can be seen as circumstantial, inferential and relies heavily on the perception of evaluators. In order to counter such perception-based evaluation, it can be proposed that because the performance of students in each course is already quantified as an integral element of their education, such quantification should, therefore, be carried over to the evaluation process of education itself. The element of intuitive evaluation in the program evaluation process cannot and should not be entirely eliminated; however, utilizing quantified indicators will provide a structure and a sense of comprehensiveness to the whole evaluation process.

This paper presents such an attempt to link the extent of student learning to the stated goals of courses (course outcomes or student learning outcomes) and the skill sets promulgated in the program charter (program outcomes) in quantifiable terms. The quantification process shows the strengths of the engineering/technology program and reveals potential improvement areas for the benefit of the evaluators and the program stakeholders alike.

Background on Course and Program Assessment

Engineering and technology programs must satisfy ABET criteria "a through k" in addition to program educational objectives to be ABET accredited. There is no doubt that at most institutions effective practices are in place for quality programs; however, the challenge to demonstrate the existing quality of these programs remains a daunting task for most institutions and associated faculty.

Koehn[1] reports on a survey-based study to assess the Civil Engineering program at Lamar University based on ABET criteria in an effort to strengthen undergraduate education. Out of the three groups surveyed (undergraduate students, graduate students, practitioners) all recommend that mathematics from calculus to differential equations as well as core civil engineering subjects be covered in depth. On the contrary, all groups rated the coverage of professional issues lower than the core technical topics. Surveys are very effective instruments in assessment and in understanding perceptions, but are not sufficient alone for ABET accreditation. Harvey *et al.* discuss direct and indirect course assessments for ABET accreditation in their computer science program.[2] Direct assessments constitute assessment methods through what is considered external entities, such as the faculty or external reviewers. Direct assessment is achieved using direct measuring instruments, such as a problem on a test, employer surveys, graduating senior surveys, or alumni surveys; indirect assessments were considered to be student self assessment surveys. The authors present the use of typical ABET-accepted rubrics to perform course and program level assessments, but the method does not appear standardized across disciplines. The presented method also does not assemble or put together the information from all courses automatically. Essa *et al.* describe a web-based tool to assist with the course assessment process for ABET accreditation.[3] The authors give the details of the design process for such a tool. The tool, though not yet fully complete by the time of publication[3], incorporates the ABET criteria into the online system to collect entries from individual instructors for their course evaluation. Although such a tool is very valuable in terms of assessing individual courses, it does not combine the information from multiple courses for a single output. Gastli *et al.* lay out the details of a course outcomes' assessment tool used at Sultan Qaboos University.[4] This tool developed at the host university was used to incorporate multiple course information for the assessment of the program, similar to what is proposed in this paper: each faculty enters the course information, grades and relevance of the course to each of the "a through k" criteria. We believe the tool proposed in this paper is simpler to use and incorporate into the program assessment process.

The Need for the Software Tool

The assessment methodology and the ClassAct© software tool was developed at Texas A&M-Corpus Christi in response to the impending ABET accreditation under the then newly implemented TC2K criteria. The Engineering Technology program at Texas A&M-Corpus Christi needed to demonstrate that in addition to the qualified faculty, modern facilities, and support from the University, alumni and industry, it had a program in place that measured and evaluated the engineering technology program's performance, and could identify areas of strength and areas that needed improvement. Such a program was necessary so that a continuous improvement strategy could be implemented. All faculty had already been using MS Excel software-based spreadsheets, albeit each one different from the other, to keep students' grades. Each course syllabus contained the expected student learning outcomes. The faculty was already overwhelmed with attending to course and students needs. The challenge was then to get the existing data on students' performance on a uniform basis, quantify the course performance, and accumulate all courses to provide an indication of the program achievements as a whole. A spreadsheet program linked at multiple levels (student grades, assessment methods, course outcomes, and program outcomes) was developed to quantify and present the results in an easy-to-understand graphical format, which identified the strengths and weaknesses not only at the course level, but also at the program level. The method has one great advantage: the quantification and bar graph representation are obtained throughout the semester as soon as the faculty enters their assessment scores semi-real time. Progress – strengths and weaknesses – can thus be tracked continuously throughout the semester. Additionally, at the end of the semester, all the individual MS Excel files collected for each course from each faculty are deposited in a file folder, and recompiled by a main program file, which pulls information from each course to assess the whole program almost effortlessly.

Assessment Approach

A student undergoing a degree program takes a series of courses of sufficient variety and increasing degree of complexity such that by the end of the degree program he or she has developed the characteristics similar to the "a through k" criteria of the ABET program outcome. In such a scheme, each course in the degree program contributes to at least one, and more likely, two or more of the program outcomes. Again, within each course a student is expected to acquire a set of skills, called course outcomes, by the time the course is successfully completed.

The assessment approach presented here presumes that in an effective, efficient and accountable program, student performance, course outcomes and program outcomes all must be intimately interconnected. All classroom activities in any given course must be in support of one or more course outcomes. In turn, all course activities must help students develop one or more of the skill subsets in the program outcomes. An additional assumption made in the ClassAct approach is that the students' performance is an indicator of the effectiveness of the program.

Thus if classroom assessment activities such as homework assignments, oral and written reports, laboratory and field exercises, quizzes and tests are linked to course outcomes, and the course outcomes, in turn, are linked to program outcomes, simple mathematical manipulations can be done to identify and quantify the strengths and weaknesses in students' development, course effectiveness and program achievements. The results can be graphically presented to allow easy interpretation and create a meaningful impact on the program stakeholders.

Microsoft Excel spreadsheet is used as the tool of choice to keep the data on student performance and the matrix of interrelationships between course outcomes and program outcomes. Most if not all academicians are familiar with this popular and easy-to-work-with spreadsheet program. The interlinked MS Excl files were referred to as *classroom assessment activities* or ClassAct© for short. The name ClassAct© and the software is currently copyrighted by the Texas A&M University system.

Meeting the ABET Requirements: Methodology and Demonstration

Using the presented software tool, it is possible to link classroom assignments and assessment activities to student learning outcomes at the course level, and program outcomes at the curriculum level. The software tool has two separate functions; the first one is to assess performance at the course level. In this case, a separate file is created for each course and the contribution of the course outcomes to "a through k" criteria is identified. The second function is to assess performance at the program level. In this case, contributions from each course to each a through k criterion is automatically generated as bar charts. The following two sections describe how the ABET requirements are achieved using the ClassAct© software in detail.

Course-Level Assessment using ClassAct©

With the ClassAct© software tool, a course is assessed along its outcomes as stated in the course syllabus. Course outcomes, also called student learning outcomes (SLOs), are commonly listed in the syllabus for the course. The SLOs are recognized typically as those that satisfy the course description and cover the major topics in the various chapters of the textbook for the course. Table 1 lists the course outcomes for a first-semester introduction to engineering technology course as an example.

Quantification method for a course, along its own outcomes, is as follows: During the semester, students are evaluated on a numerical scale in various classroom activities such as, homework assignments, oral or written reports, laboratory or field exercises, quizzes or tests, projects, and other presentations as determined by the instructor. Each of these categories of classroom activities is assigned a weight out of a total of 100. Table 2 summarizes this weighing for assignments for the introduction to engineering technology course of Table 1.

Table 1 Example of Student Learning Outcomes (Course Outcomes) in a first-year introduction to engineering technology course, as it appears in ClassAct©, directly taken from the course syllabus

#	Student Learning Outcomes
1	Describe the roles and responsibilities of engineering technologists, and what are expected of them
2	Understand and use experimental and data collection procedures used in the technical laboratory
3	Analyze experiments and experimental data
4	Identify and apply the basic principles of and scientific method of problem solving and engineering problem solving
5	Describe the operations and applications of industrial equipment
6	Identify, analyze and describe environmental, health and safety issues
7	Define professional and ethical responsibilities in the engineering profession
8	Analyze ethical issues in case studies
9	Use hardware and software tools to solve basic engineering problems
10	Demonstrate an ability to communicate effectively
11	Apply unit conversions and statistical metrics to solve problems and analyze data

Table 2 Classroom Assessment Activities

	Assessment activity	wt%		Assessment activity	wt%
1	**Tour Reports**	**8**	6	**Exam 1**	**15**
2	**Lab reports**	**10**	7	**Exam 2**	**15**
3	**HW + Quizes**	**10**	8	**Final Research P**	**5**
4	**Lego Robot Proj**	**10**	9	**Final Exam**	**25**
5	**1-Minute Engine**	**2**	10		

The instructor also records the course outcome or outcomes to which each particular classroom activity (for the above case, EACH tour report, lab report, homework assignment and quiz, the LEGO Robot Project, each 1-Minute Engineer/Technologist presentation, exam 1, exam 2, final research project, and the final exam) is related. For example, while preparing the questions for a test, the instructor determines which student learning outcome or outcomes from Table 1 are addressed by each question. This is a key component of the ClassAct© software tool in correlating class activities to student learning outcomes. Table 3 shows how each assignment is linked to the student learning outcomes it addresses.

For instance, in Table 3, the first field activity reported in Assessment Activity 1 (Tour Report 1) addresses learning outcomes 1 (describe the roles and responsibilities of engineering technologists and what is expected of them), 5 (describe the operations and applications of industrial equipment), and 10 (demonstrate an ability to communicate effectively) listed in Table 1.

Just as a student's numerical assessment is an indicator of the proficiency in the topic under consideration, the classroom average for that topic, obtained through the scores of all the participating students in the assignment, is taken as an indicator of the achievement of the course outcomes that particular topic addresses. Note that the scores for students not participating are not included, and left blank.

Table 3 Linking student assessment activity (assignment) scores to student learning outcomes (SLO) in ClassAct© software tool. In this table, the relation of the SLOs to field activities and accompanying tour reports is shown.

1		Assessment Activity				Tour Repor		
Question #		**1**	**2**	**3**	**4**	**5**	**6**	**7**
learning outcome#		1	10	5	5	1	10	
learning outcome#		5		6	6	5		
learning outcome#		10		10	10	6		
learning outcome#						10		
learning outcome#								
Points for Question	600	**100**	**100**	**100**	**100**	**100**	**100**	
student#1	379	98	90	93	98			
student#2	281	98	90	93				
student#3	576	96	99	94	92	100	95	
student#4	260	88	80	92				
student#5	412	89	80	70	73	70	30	
student#6	576	96	99	94	92	100	95	
student#7	573	95	97	93	95	100	93	
student#8	437	76	95	94		81	91	
student#9	446	100	76	95	94		81	
student#10	551	88	94	90	93	93	93	
student#11	180	92		88				
student#12	189		98	91				
student#13	290	95		98	97			
student#14	373	94	90	95			94	
student#15	580	97	95	93	98	98	99	
student#16	478		96	98	93	96	95	
student#17	269	89		88	92			
student#18	437	76	95	94		81	91	
student#19	522	93	84	86	92	93	74	
student#20	387	75	70	70	80	92		
student#21	452	96		86	95	96	79	
student#22	486	96	88	86	86	80	50	
student#23	282	98	93	91				
student#24	494	99	97	98	100	100		

Similarly, just as a student's grades are calculated based on the weighted average of the numerical scores in various classroom activities (such as lab reports, tests, quizzes and home assignments), the classroom averages of a particular topic tested at various times during the semester can be weight-averaged and the result taken to be the indicator of that particular course outcome. The final result is a profile of the course as a function of course outcomes based on the weighted average of scores. This result can be displayed in a chart for ease of interpretation and analysis. Figure 1 demonstrates this bar chart representation of percent achievement of student learning outcomes.

A bar graph representation of the class performance for each course outcome indicates the topics students mastered well or had difficulty mastering. The instructor can investigate further to discover the cause of the low scores then accordingly modify the instruction and/or test method to be more effective next time the course is offered. A basis for continuous improvement cycle is thus established.

As demonstrated in Figure 1, the ClassAct© software and methodology allows the side-by-side comparison of course assessment scores for each learning outcome (in blue or light gray) and student perceptions of their own achievement of the learning outcomes (in magenta or dark gray).

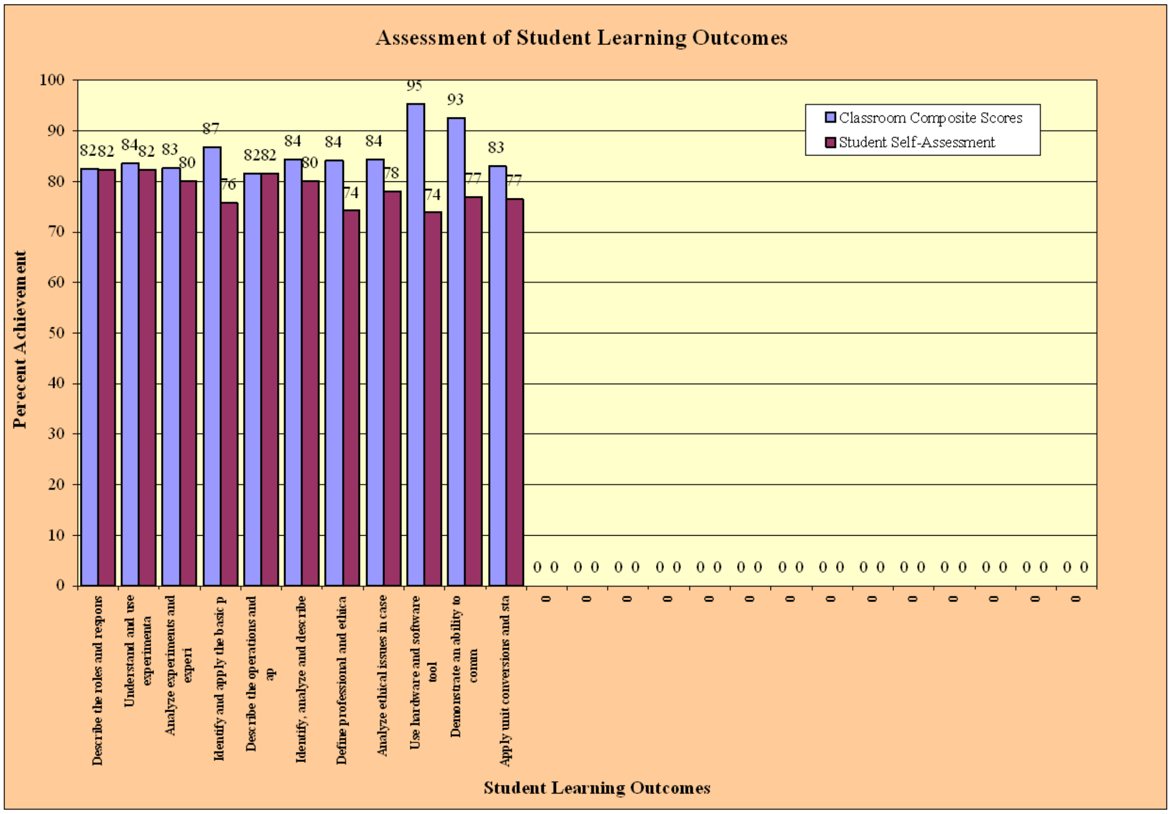

Figure 1. Degree of achievement of a course (vertical axis) as a function of course outcomes or student learning outcomes (horizontal axis).

The instructor is encouraged to state the student learning outcomes in terms of observable and measurable activities. Such verbs can be categorized according to Bloom's Taxonomy of cognitive skills. Depending upon the weights assigned to the assessment activities linked to the student learning outcomes, a Bloom's Taxonomy index can be calculated for the course. This indexing is a completely independent feature of the ClassAct assessment process. It does not affect the Course and Program assessment in any way. The objective of such an indexing is to encourage the instructors and program coordinators to ensure that as higher level courses invoke higher thinking skills from the students, as indicated by such keywords as *create*, *evaluate*, and *analyze*, compared to an introductory level course, as suggested by the keywords such as *apply*, *understand*, and *recall*.

Program-Level Assessment with ClassAct©

Assuming that the quality of students is constant, the effectiveness of a program is directly dependent upon the effectiveness of the courses that the program offers; therefore, if the various courses that constitute a program can be quantified, it should be possible to obtain a quantified index of the program. If the outcomes of a particular course and how those outcomes affect the program can be linked together through pedagogical methods, then the extent to which that particular course contributes to the program outcomes can be mathematically derived. For example, if the student is asked to submit his tour report (course assessment activity) based on the field trip activity, the student can be said to gain written communication skills (course outcome). If the student gives oral presentations of his field trip experiences, he is expected to gain oral communication skills. Communicating effectively is an ABET program outcome (g). Therefore, both the written and oral reports contribute not only to the course outcome, but also to program outcome. The number of times the reports (oral or written) are assigned and their corresponding weights will determine how influential this activity is toward meeting the communication skills program outcome. The course instructor can indicate such a relationship between the course outcomes and program outcomes in the form of a matrix. A sample matrix for the mentioned introduction to engineering technology course is demonstrated in Table 4 as it appears in the ClassAct© software tool.

Table 4 Relationship between course outcomes and program outcomes

	⇓ Student Learning Outcomes ⇓ / ⇒ Program Outcomes ⇒	Knowledge of discipline 1	Techniques of discipline 2	Skills of discipline 3	Tools of discipline 4	Apply knowledge of M&S 5	Apply knowledge of E&T 6	Adapt to emerging M&S application 7	Adapt to emerging E&T application 8	Conduct experiments 9	Analyze experiments 10	Improve process 11	Creativity in system design 12	Creativity in component design 13	Creativity in process design 14	Effective team skills 15	Identify technical problems 16	Analyze technical problems 17	Solve technical problems 18	Communicate effectively 19	Need for lifelong learning 20	Engage in lifelong learning 21	Understand professional responsibili 22	Understand ethical responsibility 23	Undersatnd social responsibility 24	Respect for diversity 25	Knowledge of professional issues 26	Knowledge of social issues 27	Knowledge of global issues 28	Commitment to quality 29	Commitment to timeliness 30
1	Describe the roles and responsibilities of engineering technologists,	2															2			3	1	1	1								1
2	Understand and use experimental and data collection procedures used	2	2	1	3	1	3					1					3	3	3	3											
3	Analyze experiments and experimental data		2	2	2	2	2	1	1	2	3	1								3										1	1
4	Identify and apply the basic principles of and scientific method of	2		2		2				3	3	2	1			2				3										1	1
5	Describe the operations and applications of industrial equipment	3	2	2	2		2																								
6	Identify, analyze and describe environmental, health and safety issues						1										1				1		2	2	2		1	1	1		
7	Define professional and ethical responsibilities in the engineering																				1		3	3	2		3	1	1	1	1
8	Analyze ethical issues in case studies																						3	3	1						
9	Use hardware and software tools to solve basic engineering problems	1	1	1	3	2	2		2	3	2	1				2	1	1	1	2	1										1
10	Demonstrate an ability to communicate effectively																			3	1		1							1	1
11	Apply unit conversions and statistical metrics to solve problems and		3	3	1	3	2			1	2								1												
12																															

In Table 4, the first two columns are the Student Learning Outcomes (SLOs) or course outcomes. The first row represents the "a through k" ABET criteria, grouped in alternating colors. In ClassAct©, each criterion (a through k) is further broken down into subcategories to assure that all facets of each criterion are captured in various classroom assessment activities.

The data from the matrices that include contributions to program outcomes from all courses can then be accumulated and weight-averaged according to their credit hours and/or year of offering (freshman, sophomore, junior or senior). The performance of the whole program can thus be profiled. Figure 2 demonstrates the contribution of a single course to the program outcomes as it appears in ClassAct© in the form of a bar graph. It is obvious that this course by itself does not contribute to every ABET criterion (see the 0 scores). It is not expected that each course in the program will contribute to all the ABET criteria; however, all ABET criteria must be addressed when contributions from all of the courses in the program are accumulated.

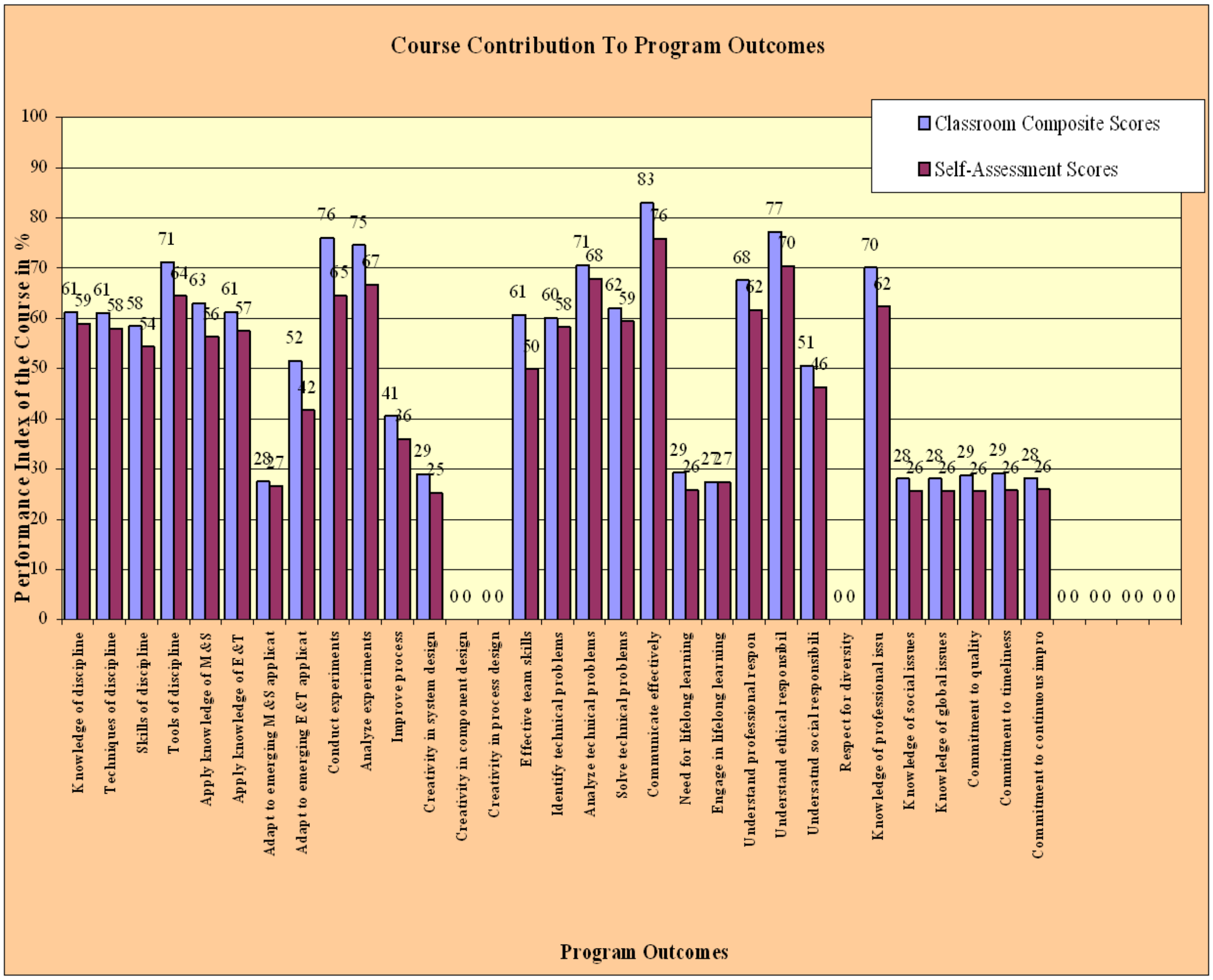

Figure 2. An example of the contribution of a single course to the program outcomes

Figure 3 shows an example of the cumulative profile of the program based on all courses in the Engineering Technology program.

These bar graphs, once again, show the strengths and potential areas of improvement for a program.

Closing the Loop

The program-level ClassAct© files can be used to close the loop in education. Based on the implications of these bar charts, deficiencies in the program can be identified and methods to address these deficiencies can be discussed. These methods may be as varied as including new topics in selected courses, modifying instructional methods, adding new assessment activities, or even introducing new courses. A continuous improvement cycle at the program level is thus started and documented for future reference.

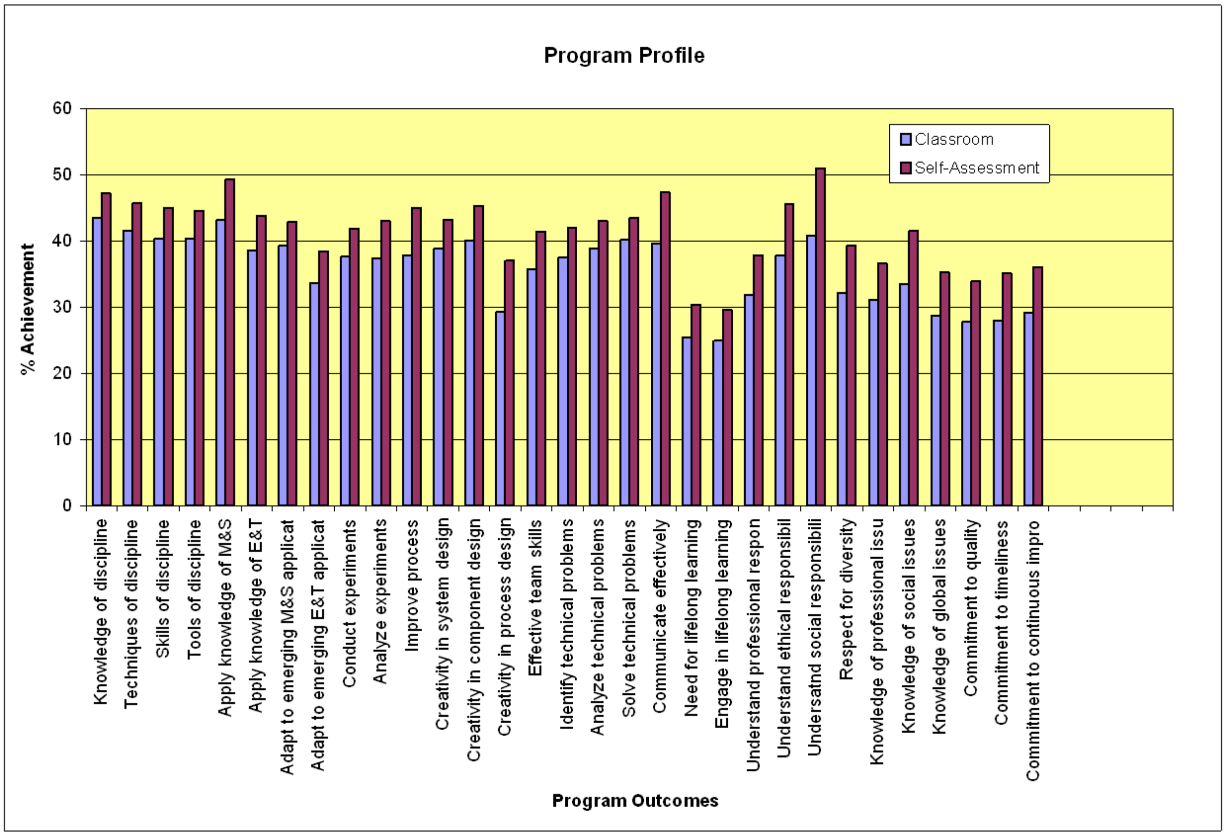

Figure 3 Program profile from cumulative contributions from courses

At Texas A&M University-Corpus Christi, closing the loop in education is achieved by archiving course-level and the program-level ClassAct© files, discussing the results with the whole department faculty to develop proper course of actions, presenting the recommendations to the program stakeholders, obtaining their approval to implement actions to strengthen the weak areas and finally implementing the action plan. The tool is applied again at the next course offering and the results of the actions taken and their effectiveness in closing the loop are monitored. Using ClassAct©, the Engineering Technology programs have been able to improve instruction and course content, and assure that all program level outcomes are addressed and evaluated. ClassAct© files have also been used in preparation for ABET accreditation revisit of the Engineering Technology programs at Texas A&M University-Corpus Christi.

Conclusions

In this paper, a software-based method for assessing student learning outcomes and program outcomes has been presented. The software tool was developed based on the need for a standardized tool within the Engineering Technology programs to assess course outcomes and program outcomes and to reduce the burden on the faculty in putting together data from various courses and facets of the program to determine the success of the program in achieving its outcomes. To perform a meaningful program-level assessment, it is important that all faculty participate in the practice of using and submitting the spreadsheets to the ABET coordinator, or lead faculty. Although not all course input may be required to show full attainment of program outcomes, certain key courses' data must be entered for a valid and complete program outcomes assessment. This software tool provides a quantifiable visual representation of the strengths and weaknesses of the program in achieving the required outcomes. Based on the visual results, the faculty can then determine steps to be taken to close the loop in Engineering Technology or any other education program. It is expected that software based assessment of outcomes will minimize bias and frustration in the program evaluation process, and increase objectivity in the review process.

Epilogue

The ClassAct© software uses mathematical tools to infer and quantify relationships between assignments, learning outcomes for each course and generate a performance profile of the whole program. The method is, therefore, dependent upon the quality of data that goes into it. Obviously, if the student quality or the grading methodology varies from one semester to another (or one campus to another), the results, arguably would not be directly comparable. This is quintessential academic question the answer to which has eluded us all to date. The question of uniformity of student quality from one year to another and the consistency of grading from one instructor to another remains unsolved by mathematical tools such as ClassAct©, remains a basic assumption and must be addressed by other means. The best advice at present is to make assessment activities as uniform in 'difficulty' as possible from one semester to another, and use rubrics for grading students' responses to decouple the variation in grading from one instructor to another. Rubrics are especially useful in tests that assess assignments involving affective skills such as writing essays and reports, and presentations based on artistic or similar skills. Using a variety of assessment methods (written, oral and motor) to obtain a comprehensive profile of student development is also recommended. Just as it is true for many endeavors that take practice, repeated use of ClassAct© allows an instructor to gain a unique orientation that helps him or her with increasing objective evaluation of the pedagogical process.

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